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FOREWORD

The International Animal Feed Symposium was designed to explore possibilities for broadening outlets for U.S. feedstuffs and to exchange information on better nutrition and more efficient feeding of livestock and poultry.

A group of 28 feed specialists from 10 countries in Europe, representing scientists in animal nutrition from universities, governmental feed control officials and feed manufacturers, were invited to participate in the Symposium with their colleagues in the United States. The basic idea of the Symposium was to get a better scientific understanding of new developments and problems in animal feeding and nutrition.

For several reasons a broad interchange of views regarding livestock feeding and feed utilization on an international level seemed worthwhile. We have seen how (1) the rapidly changing techniques of producing feed grains have materially increased production and brought total supplies to a record level; (2) the marked progress in animal nutrition and the rapid growth of the mixed feed industry have greatly changed feeding practices; (3) the general upward trend in the consumption of meat, dairy and poultry products has increased coarse grain requirements; and (4) the rising standard of living and increasing demand for protein foods have increased market prospects for feedstuffs.

True, the national agricultural conditions in the United States differ to some extent from those in other parts of the world. However, the basic principles of scientific feeding are

universal and their application as to the type of feed required to produce a specific animal (poultry, hogs, beef, dairy, etc.) depends on the prices of various ingredients, total feed requirements of the animals, the rates of substitution between various feeds, and the time required for animal growth. Advantages of feed additives have influenced the relative importance of feed ingredients in poultry and live-stock rations. These matters were discussed at the International Animal Feed Symposium.

Proceedings of the International Animal Feed Symposium held in Washington, D. C., have been reproduced so those interested in animal feeding and feed utilization may have available for study the information which was presented and discussed on this occasion.

It is hoped that the Symposium was a sound beginning for cooperatively solving animal feed problems. The problems, of necessity, are ever changing and will require our continual cooperative efforts.

Secretary

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The Dynamics of the American Feed Industry

By J. D. SYKES
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THE story of the feed industry in America cannot be separated from the dramatic development of animal agriculture in this country. Back in 1894, when the company I represent was founded, animal agriculture was in its infancy. Most chicken flocks ranged all over the farms and roosted in trees at night. To catch a hen for roasting was a major undertaking. There was little science in the feeding of poultry, beef cattle, dairy cattle, swine, or any other livestock.

In contrast, farmers today making wide use of scientific formula feeds and informed management methods are turning out high quality livestock and poultry with assembly line efficiency. Feeding operations, like industrial ventures, have become large and efficient. Big livestock and poultry feeders are highly capitalized specialists, anxious to become still more efficient.

The commercial broiler industry has sprung up from a byproduct of farm backyard flocks to an annual business of almost a billion dollars. Back in the 1930's it took 14 to 16 weeks and about 15 pounds of feed to grow a 3-pound chicken. Today many commercial growers are producing choice 3-pound birds in a little over 8 weeks on as little as 7 pounds of feed.

In the 1930's it used to take about 7.5 pounds of feed to produce a dozen eggs. Many feeders today with top laying strains of hens are producing a dozen eggs on

an average of a little more than 3 pounds of feed. The resulting advantages to the consuming public in economy and quality of food are readily apparent. If feeds and methods of the 1930's were used by poultrymen today, eggs probably would cost the consumer around $2 a dozen or more. This would put eggs in the category of a delicacy, rather than a staple food within the economic reach of everyone.

A generation ago it took an average of 10.9 pounds of feed to produce a pound of beef. Good feeders across the country are now producing a pound of beef on an average of less than 7.5 pounds of feed.

A generation ago pork was being produced on an average of 5.1 pounds of feed for each pound of meat. Today good hog raisers feeding good commercial supplements are producing pork at the rate of one pound of meat on about 3.2 pounds of feed, a 37 percent improvement over a generation ago.

The development of the formula feed industry in America can take modest claim for a share of these dramatic improvements in feed efficiency. This progress in feeding livestock and poultry has been important in making America well-fed. It has made possible the production of an abundance of highest quality human food at prices the general public can pay.

Animal agriculture, the production of animal and poultry products, has become a gigantic business in this country with an annual volume of some $16 million. Having established its critical importance to modern animal agriculture, the feed industry has become the largest industry serving agriculture, with an annual volume of some $3½ billion.

In the 10 years after World War II we in the United States ate on the average of 20 pounds more red meat per person than we did in the 10 years before the war.

In 1958 our people ate an average of 87.3 pounds of beef and veal per capita, 60.5 pounds of pork, 4.1 pounds of lamb and mutton, 28.5 pounds of chicken, and 5.6 pounds of turkey. They each consumed an average of 345 pounds of fluid milk and 350 eggs.

A national diet containing such liberal supplies of the

protective foods, meat, milk, and eggs, cannot help but contribute greatly to the health, vigor, and ability of a nation.

The feed industry in America has made its contributions to this national strength. Many of the achievements of the feed industry have been made easier by what could be called "cooperative competition" within the industry. Several separate feed mills in this country mix their own brands of feed. Many are small local mixers. Others are large organizations that distribute their products regionally, nationally, or internationally. Competition is keen.

However, cooperation between these competitors is deep-rooted, too. Our national trade association, The American Feed Manufacturers Association, brings all segments of the industry together in friendly businesslike cooperation. We discuss problems and exchange ideas with each other. We seek solutions to common problems. Then we each go out and compete for the customers' business.

Competition has inspired much of America's agricultural and industrial strength. We in the feed industy welcome good honest competition because we know it will make our own companies better and the industry more useful. Cooperative competition has been a force in the development of our feed industry.

The tonnage growth of manufactured feeds during the past 25 years or so illustrates the dramatic development of the feed industry. In 1932, only 6.2 million tons of commercial feeds were manufactured in this country. In 1942 there were 12.3 million tons. By 1950, commercial feed production had increased to 29.1 million tons. Last year, in 1958, approximately 40 million tons of commercial feeds were manufactured and fed in the United States.

Economic Aspects of Feed Grain Supplies

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THE Nation's feed industry has fully shared in the technical and economic forces affecting our national economy during the past 2 or 3 decades. Rapidly changing techniques of producing feed grains have materially increased feed grain production and brought total supplies to a record level. Feeding practices also have undergone marked changes making our feed picture much different from that of 20 or 30 years ago. A number of developments have been important in changing feed supplies and utilization. Many of these will continue to play important roles in the future. Economic and technical developments experienced in our country have been more or less important in most countries. In Western Europe changing patterns in the feed situation have been similar in many respects to those in the United States.

Let us begin by listing a few of these developments:

1. Improvement in the techniques of producing feed grains. Development of higher yielding varieties, better cultural practices, increased fertilizer application and improved machinery have materially changed production practices and greatly boosted yield per acre.
2. Transition from the use of horses or other workstock for farm power to the use of tractors and trucks. This has released feed crops for use in production of livestock food products.
3. General upward trend in the consumption of meat, dairy

products. poultry and eggs. This is increasing coarse grain requirements.

4. Marked progress in animal nutrition and the rapid growth of the mixed feed industry. These have greatly changed feeding practices, and have been especially important in poultry feeding.

Higher Yields Per Acre

Considering these developments individually, probably none has been more important to the current coarse grain situation than the upward trend in yield per acre. While there has been a steady upward trend in yields for a number of years, increases have been especially pronounced in the last decade. The combined yield of the four major feed grains in the United States in 1958 was more than 50 percent above the 1937—41 average. In recent years, the dominant factor causing higher yields has been the increased use of commercial fertilizer. Over a longer period, improvement in varieties of coarse grains, along with the development of corn and sorghum hybrids, has been important.

Near record yield per acre of feed grains in 1956 was followed by record yields in 1957 and 1958. Influenced by a very favorable growing season, record yields per acre were realized in 1958 for each of the four feed grains.

Use of commercial fertilizer has increased nearly fourfold since 1935—39. In recent years the trend toward heavier application of nitrogen fertilizer has probably been more important than any other factor in raising corn yields.

Less Feed Required for Workstock

Mechanization in agriculture has contributed directly to larger production of feed crops. However, its major contribution has been in replacing workstock on the farm and reducing the number of man-hours required to produce feed grains and other crops. In the United States, the changeover from horses and mules to tractors and trucks for farm power has nearly run its course. The number of horses and mules now on farms is only about a tenth what it was 40 years ago.

The impact of this transition on the feed situation can easily be underestimated. Forty years ago horses and mules in

our country consumed about 27 million tons of coarse grains. At present, they consume only about 2 million tons. Thus, 25 million tons of grain that once went into farm power is now available for production of meat, dairy products, poultry and eggs. Without this reduction in horse and mule numbers, we would be under pressure to produce enough coarse grains to meet our growing needs.

Feed saved through declining numbers of horses and mules has gone into other types of livestock production. Production of hogs, cattle, dairy products, poultry and eggs have all trended upward for a number of years. In recent years the overall increase in the output of these products has more than kept pace with our increasing population. In the past 10 years total livestock production has increased more than 20 percent. Poultry and egg production has gone up over 40 percent, meat animals 23 percent and dairy products about 11 percent.

Livestock Production Expanding

Livestock production also has trended upward sharply in a number of other countries, particularly those of Western Europe. Heavier consumption of meat, milk and eggs in recent years reflects general prosperity of the period and changing consumer demand from starchy foods to livestock products. In most of the European countries, the increased production of coarse grains has gone into increased output of livestock products. A number of these countries also have increased imports to meet the growing demand for livestock products. In the United States on the other hand, increasing feed grain production has more than kept pace with increasing consumption and stocks have accumulated.

In postwar years, there also have been some marked changes in feeding practices. In this country there has been a very rapid expansion in the mixed feed industry. Production of commercially prepared feeds has more than doubled during the past 20 years and livestock and poultry rations are much better balanced in protein and vitamin content.

The total tonnage of high-protein feeds fed to livestock (in terms of soybean meal equivalent) has increased from less than 6 million tons in the late 1930's to about 15 million tons this year. Nearly all of this increase is due to the marked upward

trend in production of soybean meal. Soybean meal has become an important protein ingredient of all kinds of livestock and poultry rations. This year close to 9 millon tons of soybean meal will be fed, or about 60 percent of the total tonnage of high-protein feed.

Feed Grain Stocks at Record Level

The feed situation in the United States in recent years has differed from that of most other countries in one important respect. In this country, there has been a substantial build-up in feed grain stocks. Canada is the only other country where there has been a substantial accumulation of stocks in the postwar years. In 1958 Canadian stocks of oats and barley totaled over 5 million tons, or about 40 percent of average production. But Canadian stocks are only a fraction of the record tonnage held in this country.

These big stocks have resulted from the big feed grain crops in this country, which have consistently exceeded total consumption and exports each year since 1952. While this disparity has not been great relative to total production, it has been such as to add 4 to 10 million tons to our total stocks each year.

The total carryover of the four feed grains increased from 20 million tons in 1952 to 59 million in 1958. All of this increase in stocks has gone into Government holdings as farmers have delivered substantial quantities of grain to CCC each year under the price support program. Nearly 85 percent of the record 1958 carryover stocks were owned by CCC, or were under the Government loan program. A further increase is in prospect during 1958-59, with total stocks expected to increase to around 70 million tons at the beginning of the 1959-60 marketing year.

Supplies of each of the four major feed grains have increased in recent years. The 1958-59 corn supply exceeded 5 billion bushels for the first time. It is more than a billion bushels above the 1949—53 average. The resulting supply is much more than ample to take care of prospective domestic use and exports. Increased livestock population this year, however, is consuming much more corn than in 1957-58. Present indications are that around 3.7 billion bushels will be consumed

domestically or exported. In this event, the corn carryover next October 1 would total around 1.6 billion bushels, 130 million more than on October 1, 1958.

Combined supplies of the other three feed grains have increased more sharply than corn during the past 2 years. The 1958-59 sorghum grain supply of over 900 million bushels is more than 3 times the supply of only 2 years ago. The sorghum grain supply now exceeds barley in total tonnage and is nearly equal to the total tonnage of oats. Big supplies of oats and barley also are on hand for 1958-59. Record carryover stocks of each of these three grains are in prospect for the close of the 1958-59 season.

Total feed concentrate supplies, including these big supplies of feed grains and high-protein feeds, have increased sharply during the past 2 years following a more moderate increase during the period 1952—56. This is the fifth year of record feed concentrate supplies. Increasing supplies in recent years reflect both mounting stocks and increasing production.

Feed Grain Prices Decline

Increasing feed grain supplies in this country have been accompanied by generally declining prices. The short 1947 corn crop resulted in feed grain prices rising sharply to a record high in 1947-48. Prices dropped sharply with the harvesting of the big 1948 crops, then rose again reflecting increasing demand during the Korean conflict. Since 1952 feed grain prices have declined, reflecting, in part, the big crops in these years which have exceeded domestic use and exports.

Feed grain prices also were influenced by declining demand after the Korean conflict. Livestock prices declined nearly 30 percent from 1951 to 1956. In 1957 and 1958, however, prices of livestock and livestock products rose fairly sharply. Prices of feed grains continued to drift downward and feed prices have been unusually low during the past year or so in relation to livestock prices. Relatively favorable feed prices are basic to the increase in production of hogs and other livestock now underway.

The Government price support program also has had an important bearing on feed grain prices. Price support for each of the four feed grains have been lowered in recent years as feed

grain stocks have increased. The recently announced supports for 1959 are the lowest for the postwar years. The corn support, of $1.12 per bushel is 30 percent below the supports for 1952 and 1953, while supports for the other three coarse grains are more than a third lower than the postwar peak of 1953.

Exports Up Sharply

Increasing feed grain production, lower prices and mounting stocks of Government owned coarse grains in this country have been accompanied by increasing livestock production and rising demand for coarse grains in other countries, especially in Western Europe. These developments have been basic to increasing exports of each of the four coarse grains during the past 5 years. Total exports of coarse grains from the United States in the 1957-58 marketing year reached a new record of nearly 10 million short tons. This was more than a fourth larger than in 1956-57 and double exports of 5 years ago. United States exports made up nearly half the world total. During the current marketing year, United States exports are expected to exceed last year's record.

Europe continues as the biggest U.S. market for coarse grains. In 1957-58 nearly 6 million tons were shipped to Europe, nearly two-thirds of the total exports. The United Kingdom, the Netherlands, Belgium and Luxembourg, and Western Germany were the heaviest buyers of U.S. coarse grains. Shipments to the Western Hemisphere, principally to Mexico and Canada, totaled about 1.8 million tons, or nearly a fifth of the total. Buyers in Asia, principally Japan, South Korea and Israel took another 15 percent accounting for most of the remainder.

Big Stocks Important Factor in Outlook

In closing, I would like to turn again to the big stocks of coarse grains that will be on hand at the beginning of the 1959-60 marketing year. That is, the total tonnage of oats and barley that will be on hand this July 1 plus the corn and sorghum grain that will be on hand next October 1. As pointed out earlier, these big stocks are expected to total around 70 million tons. Probably no other single factor is as important in

the outlook for feed grains over the next few years as these big stocks. They will play a major role in the overall feed situation whether we have years of short crops, or average or better than average crops.

Comparisons are shown here as to how these stocks measure up to average production, the feed required by our annual pig crop and the deficit resulting from a severe drought year. In these comparisons, allowance is made for what might be considered a "normal" carryover. The stocks above "normal" stocks may be considered as available for use without reducing carryover to an undesirably low level. For the purpose of these comparisons, the "normal" carryover is taken as 20 million tons. The 70 million ton carryover in prospect for 1959-60, less the 20 million tons allowance for "normal" carryover, would leave prospective stocks above this "normal" of around 50 million tons. It is not the intention here to imply that these are entirely surplus stocks. They may turn out to be, at least in part, a desired reserve, depending on circumstances of the next several years.

These above "normal" carryover stocks of 50 million tons would be nearly 40 percent of the 1953—57 average production. They would be sufficient to fully make up for the deficit of a very unfavorable season in this country such as 1936 or 1947 and still leave at least a "normal" carryover at the close of the year.

Such stocks would be sufficient to take care of our present livestock requirements for about 5 months of the feeding year. In terms of feed required for producing our pig crop, these stocks would be about equal to the total tonnage of feed required to produce our combined spring and fall pig crops of recent years.

Our stocks loom very large in relation to our annual exports. While increased exports have proved an outlet for substantial quantities of feed grains in recent years, they have been a relatively minor outlet, compared with the total tonnage now on hand. Carryover stocks above the "normal" level are 5 times the record exports of 10 million tons for 1957-58. Thus, these stocks could serve as a reserve for continued heavy exports and increasing livestock production in foreign countries, as well as for possible emergency needs in our country.

How to Buy Feed Grain and Protein Supplement

By LEONARD W. SCHRUBEN
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AT any given time and place, the price of one feed grain is almost always as low or lower than any of the others relative to specific feeding values and within limits imposed by the ability of livestock being fed to utilize different grains. This same principle applies to the selection and use of feedstuffs high in protein.

In the case of both grains and protein supplements, special situations may call for a specific kind of feedstuffs. These are rare as far as commercial animal production is concerned.

Least-Cost Grain

The fact that one feed grain usually is a better buy than all others gives us a basis for placing a dollar sign on grains. For example, suppose you wish to compare corn and milo prices. If we assume that corn is worth $1.00 per bushel then we have the following relationships: When fed to dairy cows, for wintering beef cattle, or fattening lambs, milo is worth $1.79 cwt; when used to fatten beef cattle, and fatten hogs, milo is worth $1.70 cwt. These relationships of market price are based on relative nutritional values.

Different kinds of feed grains can be used in a ration to produce a given quantity of livestock or livestock products. This is the starting point for price comparisons. Experimentation by workers in animal nutrition has given us a basis for

the relative feeding value of different grains, generally a per pound basis.

TABLE 1

Relative feeding values of a pound of Kansas grain [1]

Grain	Use			
	Feeding dairy cows	*Fattening beef cattle*	*Fattening hogs*	*Fattening lambs*
Corn	100	100	100	100
Wheat	100	105	105	85
Barley	100	88	91	87
Sorghum	100	95	95	100
Oats	95	85	85	90

1 Assumes fed in a balanced ration, and will be properly prepared and is of average quality.

It is a common practice to compare the feeding value of a pound of each of the grains in terms of a pound of corn. In order to compare prices, adjustment is necessary to account for the fact that market quotations are in units of 56 pounds per bushel of corn, 60 for wheat, 48 for barley, and 32 for oats. Sorghum grain is commonly quoted on the basis of a hundred pounds, although a bushel weighs 56 pounds.

Each grain may have different values when fed to different kinds of livestock. Sorghum grain, for example, is generally not considered to be worth as much relative to corn when used to fatten hogs as when fed to dairy cows. Fed to dairy cows, sorghum grain is considered to have a value equal to corn but only approximately 95 per cent of the value of corn when fed to hogs.

As more knowledge is gained as to better methods of preparation, these substitution relationships also would be changed if farmers changed feeding practices. If we learn a more efficient way of feeding sorghum grain and do not learn a more efficient way of feeding corn, the relationships would be different than those indicated in table 1.

To be sure, there is some room to dispute the precise values given in table 1, because of some variation in the results achieved by different experiments. However, with only a small margin of possible error, they are defensible. Until methods of feeding are developed and followed which will change these basic relationships, this information can be used as a basis for comparing market prices with nutritional values.

If you were fattening lambs, wintering cattle, or operating a dairy and could save $10 on every ton of grain you fed, would you be excited about it? If you were fattening hogs or cattle and could save 30¢ a 100 pounds of the grain part of that ration, would you be willing to switch to the more economical grain? Savings of these amounts have been realized as I will now show.

Habit can make life easier, but feeding the same kind of grain to livestock without comparing prices can be costly. For example, in my area of the United States the advantages milo frequently has over other grains are not always recognized. Maybe this is because sorghum has had a long history as a roughage source. Only in recent years have we thought of milo, as sorghum grain is known in the trade, as a major feed grain. It is time this thinking is changed and that old habits are challenged.

Sorghum has origins in antiquity, but the crop we are discussing is new. It is fresh from the research laboratory and test plots. We are now seeking a market for this product of research.

Adaptation of varieties, irrigation, and problems of harvesting and storage are being solved. This means a more dependable source of feed grain appears to be well within reach for the world market.

Sorghum Grain and Corn in Kansas

How does sorghum grain compare with other feed grains? Suppose for the moment you are a dairy farmer in Kansas and you usually feed corn. Savings of $12 per ton or more could have been realized at certain times the past 3 years had you switched from corn to sorghum grain (table 2).

TABLE 2
Sorghum grain : Kansas farm price and feeding value equivalent based on corn prices, 1956—58

Month and year	*Sorghum grain prices (per cwt.)*	*Prices of equal feeding value as corn*		*Feeding value above (+) or below (—) Actual price*	
		Dairy and lambs	*Hogs and cattle*	*Dairy and lambs*	*Hogs and cattle*
	Dollars per cwt.	Dollars	Dollars		
1956:					
January	1.81	2.30	2.19	+.49	+.38
February	1.82	2.30	2.19	+.48	+.37
March	1.83	2.32	2.21	+.49	+.38
April	1.90	2.50	2.37	+.60	+.47
May	2.03	2.64	2.51	+.61	+.48
June	2.16	2.62	2.49	+.46	+.33
July	2.23	2.66	2.53	+.43	+.30
August	2.30	2.70	2.66	+.40	+.26
September	2.10	2.43	2.31	+.33	+.21
October	2.15	2.32	2.21	+.17	+.06
November	2.23	2.37	2.26	+.14	+.03
December	2.27	2.43	2.31	+.16	+.04
1957:					
January	2.23	2.43	2.31	+.20	+.08
Februar	2.19	2.36	2.24	+.17	+.05
March	2.18	2.36	2.24	+.18	+.06
April	2.16	2.34	2.22	+.18	+.06
May	2.02	2.34	2.22	+.32	+.20
June	1.94	2.32	2.21	+.38	+.27
July	1.89	2.36	2.24	+.47	+.35
August	1.85	2.34	2.22	+.49	+.37
September	1.38	1.95	1.85	+.57	+.47
October	1.22	1.73	1.65	+.51	+.43
November	1.32	1.80	1.71	+.48	+.39
December	1.40	1.84	1.75	+.44	+.35
1958:					
January	1.46	1.84	1.75	+.38	+.29
February	1.50	1.79	1.70	+.29	+.20
March	1.58	1.82	1.73	+.24	+.15
April	1.69	1.91	1.82	+.22	+.13
May	1.67	1.96	1.87	+.29	+.20
June	1.68	2.04	1.93	+.36	+.25
July	1.74	2.07	1.97	+.33	+.23
August	1.80	2.05	1.95	+.25	+.15
September	1.60	1.82	1.73	+.22	+.13
October	1.37	1.64	1.56	+.27	+.19
November	1.48	1.61	1.53	+.13	+.05
December	1.56	1.73	1.65	+.17	+.09

Here is how to read table 2. Suppose you are feeding dairy cattle and you want to compare corn and sorghum grain prices in January, 1958. First, note the column giving the year and the month. Find January, 1958. In the next column you will find the Kansas farm price of sorghum grain. It was $1.46 per hundred.

In the next column you will find a $1.84. This is the price you would have paid for equal feeding value had you paid the going price for corn. This same price would hold if you were fattening lambs. The difference between $1.46 and $1.84 is the saving you could realize by feeding sorghum grain, instead of corn, to dairy cows.

The third column of figures shows the cost of corn had you bought equivalent feeding value for fattening cattle or hogs. You will note the figures in this column are smaller than when fattening lambs or feeding dairy cows. This is because, as commonly handled, sorghum grain is not worth quite as much relative to corn when fattening beef cattle or hogs. So the cost of feeding valued equivalent in corn would not be so high.

The last two columns in table 2 show the saving you could have realized by using sorghum grain compared to corn. Month-by-month comparisons are shown for the past three years. A + in front of the price in these columns means grain sorghum had an economic advantage over corn in competing for inclusion in livestock ration in Kansas.

Note, all the numbers have a + sign. During this 36 months period, had you bought at average midmonth Kansas prices there wasn't a single month that sorghum grain didn't have a price advantage over corn.

Buying Protein Supplement

Some feed buyers assume "the market" will even out prices they pay for protein supplement. Therefore, they buy the same kind each time without going to the trouble of comparing prices.

This habit is costly. Almost always one supplement is cheaper than any other at any given time and place relative to what it will do in the feedlot. You cannot rely upon this thing called "the market" to keep prices in line.

It is true that over the long pull market prices will average out about the same as feeding values. But you do not buy on the average. Sometimes we talk about the right time of year to buy and forget to get a good buy today or this week.

Often the market offers an opportunity to lower costs of farm production. One such opportunity is in the purchase of protein supplement. You should buy the cheapest relative to the job it will do in the feedlot. It sometimes is difficult to tell which is the cheapest. Some supplements contain 32 percent protein, some 41 percent, and others 44. Tankage will run as high as 60 percent. You can tell by reading the tag on the bag.

One common method of comparing prices of supplements is to figure the cost per pound of protein. For example, a 41 percent protein meal has 820 pounds protein per ton (41 percent for 2,000 pounds). You divide this 820 pounds into the price per ton and your answer is the cost per pound of protein. Likewise a supplement with 60-percent protein would have 1,200 pounds per ton. Divide the price per ton by 1,200 and you have the cost per pound of protein. Do this for the sources of protein available to you and you have your basis for comparison of prices.

Of course, there is more nonprotein in the supplement with 41 percent than in the one having 60 percent. An allowance should be made for this fact. The nonprotein usually is not worth nearly as much as the protein part and the common rule of thumb is to allow about the same price for the nonprotein pounds as you would for the price of corn.

Kansas Protein Prices

Prices of protein supplements vary considerably in different parts of Kansas. The best buy in one town might not be the best buy in the next. At any given time one protein supplement almost always will be a better buy than another. Therefore, it pays to shop and it pays to compare prices with feeding values.

TABLE 3
Soybean meal and cottonseed meal, prices paid by farmers, Kansas, 1956—59

Month and year	*Soybean meal price*	*Cotton-seed meal price*	*Price of protein*[1] *Soybean meal*	*Price of protein*[1] *Cotton-seed meal*	*Price of protein*[1] *Soybean meal above (+) or below (−) cottonseed meal*
	Dollars per cwt.	Dollars per cwt.	Cents per lb.	Cents per lb.	Cents per lb.
1956:					
January	3.80	3.75	8.6	9.1	−0.5
February	3.75	3.70	8.5	9.0	− .5
March	3.70	3.65	8.4	8.9	− .5
April	3.70	3.60	8.4	8.8	− .4
May	3.95	3.65	9.0	8.9	+ .1
June	4.00	3.65	9.1	8.9	+ .2
July	4.10	3.70	9.3	9.0	+ .3
August	3.95	3.80	9.0	9.3	− .3
September	3.90	3.80	8.9	9.3	− .4
October	3.75	3.70	8.5	9.0	− .5
November	3.70	3.75	8.4	9.1	− .7
December	3.70	3.75	8.4	9.1	− .7
1957:					
January	3.70	3.80	8.4	9.3	− .9
February	3.70	3.80	8.4	9.3	− .9
March	3.65	3.75	8.3	9.1	− .8
April	3.60	3.70	8.2	9.0	− .8
May	3.60	3.65	8.2	8.9	− .7
June	3.55	3.65	8.1	8.9	− .8
July	3.60	3.65	8.2	8.9	− .7
August	3.65	3.65	8.3	8.9	− .6
September	3.70	3.65	8.4	8.9	− .5
October	3.65	3.55	8.3	8.7	− .4
November	3.55	3.50	8.1	8.5	− .4
December	3.50	3.55	8.0	8.7	− .7
1958:					
January	3.50	3.60	8.0	8.8	− .8
February	3.50	3.60	8.0	8.8	− .8
March	3.60	3.65	8.2	8.9	− .7
April	3.85	3.65	8.7	8.9	− .2
May	3.90	3.65	8.9	8.9	0
June	3.85	3.65	8.7	8.9	− .2
July	4.10	3.70	9.3	9.0	+ .3
August	4.25	3.75	9.7	9.1	+ .6
September	4.05	3.70	9.2	9.0	+ .2
October	3.90	3.60	8.9	8.8	+ .1
November	3.70	3.65	8.4	8.9	− .5
December	3.90	3.85	8.9	9.4	− .5
1959:					
January	4.10	4.15	9.3	10.1	− .8
February	4.05	4.20	9.2	10.2	−1.0

[1]Soybean meal computed at 44% protein; cottonseed meal computed at 41% protein.

Data in table 3 illustrates how these prices change from month to month. Prices per hundred pounds of ingredient are shown in the first part of the table. Next, a computed cost-per-pound of crude protein is given. In the last column you will find a comparison between the price of a pound of protein in soybean meal and cottonseed meal. These meals are the principal sources of protein used in Kansas.

You will immediately notice that protein has been priced higher in cottonseed meal than soybean meal most of the time the past three years. This is in Kansas.

Summary

There is one outstanding lesson to be learned by comparing feed prices with feeding values. It is that market prices will not always reflect feeding values. In order for you to obtain the greatest benefit from your feed dollar you must be alert to price changes.

You must be ready to substitute one kind of feed for another. To do this you need to establish the degree of substitution possible among the different ingredients. Research in animal nutrition, a knowledge of actual feeding practice, and good judgment in adapting rations will provide a foundation for determination of the economics of feed substitution.

Mineral Deficiencies and Mineral Requirements of Livestock

By G. K. DAVIS
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BY far the largest loss in livestock resulting from mineral deficiencies comes from the borderline deficiencies rather than the severe, acute conditions. A severe deficiency is obvious and livestock men usually try to correct the apparent disease. With a borderline deficiency, no definite symptoms appear, and perhaps the most important change is that the animals perform with a reduction of perhaps 10 to 20 percent in efficiency. To prevent these borderline or subclinical conditions, attention must be given to meeting the requirements of minerals for adequate nutrition.

Deficiencies

The dramatic results which have been obtained from feeding very small amounts of copper and cobalt have focused attention on mineral deficiencies, but the most common deficiency and the one which causes greatest loss to livestock is a deficiency of phosphorus. A severe deficiency of phosphorus often passes for a severe attack of parasites, some wasting disease or just plain starvation. With a deficiency of phosphorus, an animal is not able to utilize feed even when given more than required for normal performance and reproduction. The animal may lose weight, and since fat metabolism is particularly concerned, a deficiency of phosphorus prevents fattening. The hair coat becomes rough, the shoulder blades have a tendency to "wing out", bones become thin and bone fractures are a commonly observed injury. Reproduction and

lactation are sharply reduced and may approach zero. In cattle, a depraved appetite is a common result of phosphorus deficiency. Cattle suffering from phosphorus deficiency will consume almost anything, ranging from rubber tires and boards to bones. One of the most common displays put on by investigators in this field has been that of a great variety of objects found in the rumen-reticulum of a phosphorus deficient animal.

Phosphorus normally makes up about 1 percent of the animal body and is an element most likely to be in subnormal supply. From the standpoint of economics, greatest total losses come from the borderline deficiency in which the animals show a somewhat lower lactation than would be expected from the feed consumed, a slower growth rate and in general somewhat less than optimum performance. It is difficult to diagnose such a deficiency by examining the animal. Chemical determinations of blood phosphorus, feed composition and observations on overall performance are necessary before the deficiency can be diagnosed.

Normally, the inorganic blood phosphorus has been a good measure of phosphorus nutrition for animals (table 1). Unfortunately, a normal value does not always assure one that the animal is receiving normal phosphorus nutrition. An animal that is excited or that has received a phosphorus supplement a few hours to a day before the blood sample is taken may show a high value. On the other hand, if a low value

TABLE 1

Plasma inorganic phosphorus and dietary phosphorus requirements for adequate nutrition

Species	*Plasma Inorganic P*		*Normal growth and maintenance dietary requirement*		
	Young	*Mature*	*Young*	*Mature*	*Lactating*
	Milligrams percent	Milligrams percent	Percent	Percent	Percent
Dairy cattle	5-7	4-5	0.30	0.13	0.25
Beef cattle	5-7	4-5	.21	.15	.18
Sheep	5-6	4-5	.19	.16	.20
Swine	5-8	4-6	.45	.4	.4

is obtained under these conditions it is almost conclusively diagnostic of a deficiency situation in the nutrition of the animals.

Since phosphorus deficiency occurs on pasture or under pasture conditions most commonly, we frequently analyze pasture for the phosphorus content. Phosphorus values that are below 0.16 percent on a dry-matter basis may be considered suspect of a deficiency condition. Values of 0.18 to 0.2 and above are adequate and will supply all the phosphorus required by grazing animals. Under the most common conditions, it is necessary to supply grazing animals with a source of phosphorus. If the phosphorus level cannot be maintained in the pasture through fertilization then a mineral supplement is in order and should be made available on a free-choice basis.

Calcium is the other principal mineral of the animal body, making up about 1 to 1.5 percent of the body composition. Calcium frequently becomes a limiting factor in the nutrition of livestock. Since bones store calcium and if calcium can be supplied, even irregularly, in the diet, a deficiency is much less likely to occur than is the case with phosphorus. A deficiency of calcium in lactating animals will result in a severe depression of milk flow and in fact in cattle may result in from 25 to 40 percent less milk being given than if a supplement supplied adequate calcium to the animals.

While calcium is important to the lactating animals, it is not as likely to be deficient in the diet of beef cattle and sheep as it is in the case of dairy cattle. Calcium is extremely important for those animals the diets of which are largely made up of grains and byproducts. Swine and poultry particularly, but also fattening cattle, must have calcium supplements if they are to maintain a satisfactory calcium to phosphorus ratio and a satisfactory utilization of their feed. It is well to try and maintain a ratio of somewhere between 2 to 1 and 4 to 1 of calcium to phosphorus in the feed. The lower ratio of 2 to 1 being somewhat better than higher ratios. The ratios which deviate from the optimum of from 1 to 1 to 2 to 1 are particularly damaging when the intake of calcium and phosphorus is limited. Table 2 gives the calcium requirements of cattle, sheep, and swine.

TABLE 2
Calcium: Dietary requirements by type of animal

Type	*Requirement for*		
	Young	*Mature*	*Lactating*
	Percent	Percent	Percent
Dairy cattle	0.26	0.14	0.30
Beef cattle	.29	.14	.24
Sheep	.21	.20	.28
Swine	.65	.60	.6

Sodium and potassium usually are not mentioned in discussions of minerals simply because everyone takes them for granted. It is probably true that potassium is supplied in abundance where pastures make up a large part of the feed. It is only with animals such as poultry and swine and then with difficulty that a potassium deficiency may be produced. Cattle may have a need for extra sodium.

Because salt is usually considered a part of good animal husbandry, it is frequently forgotten that cattle may develop a need for a common salt with many of the symptoms of other deficiencies. Since salt is such a common and such an economical source of mineral it is foolish for livestock men not to keep adequate salt before cattle at all times.

In table 3, is presented a listing of the cobalt, copper, iron, and zinc requirements for cattle, sheep, and swine. Cobalt deficiency occurs in almost all of the areas of the world where there has been prolonged cropping of the fields without replace-

TABLE 3
Cobalt, copper, iron, zinc:
Dietary requirements, by type of animal

Type	*Cobalt*	*Copper*	*Iron*	*Zinc*
	Ppm[1]	Ppm	Ppm	Ppm
Dairy cattle	0.07	5	80-150	30
Beef cattle	.07	5	80-150	30
Sheep	.08	5	80-150	30
Swine	.04	4	80-150	40-50

[1]Ppm=parts per million.

ment of the cobalt through fertilizer. This is a broad statement, yet the more we investigate cobalt and animal need for it, the more we are sure that a borderline deficiency of cobalt may be a frequent unrecognised limiting factor in the production of cattle or sheep. One of the reasons why cobalt deficiency is not recognized more often is that it looks like a simple case of starvation. Animals in this condition are anemic, poorly fleshed, and usually fail to shed out their hair coat. They have a poor reproduction and lactation record, and young animals grow very poorly. All of these symptoms are duplicated by starvation with the exception of the anemia, and the anemia is characteristic of parasitism.

As a result of this similarity between starvation and parasitism, cobalt deficiency is often treated as if it were a heavy infestation of parasites. The situation is further complicated by the fact that in most instances of cobalt deficiency the weakened animals may be more susceptible to parasites.

Cobalt deficiency is essentially a problem of sheep and cattle. In both these species cobalt serves as a part of vitamin B 12 and it would appear that this is the principal, if not the only function of cobalt in the animal body.

Under most circumstances, cobalt is best given to the grazing animals in the form of a mineral supplement, since it has no beneficial effects on plant growth and is applied in the fertilizer only in order to supply the needs of the animals. On the other hand, where cobalt can readily be included in super phosphate and where leaching is not a problem, application as a fertilizer at the rate of approximately 1 pound of cobalt sulfate per acre is a satisfactory method of supplying cobalt.

Copper deficiency (and with it, molybdenum toxicity) is a problem of the peat or high organic soils throughout the world. Copper deficiency is not limited to the peat soils, but because peat soils are particularly deficient in copper, the deficiency condition tends to be most severe in these areas. The first result of copper deficiency is an anemia. This anemia is the result of poor utilization of iron. With copper deficiency, cattle often develop livers that are extremely high in iron. In our own laboratory, we have found values as high as 5,000 to 6,000 parts per million of iron in cattle livers. Livers have been

sent to us from other areas of the world that have run as high as 35,000 to 40,000 parts per million of iron. Apparently, with a deficiency of copper, iron cannot be utilized and is stored in the liver where it may cause some damage to the liver tissue.

Under normal conditions, copper is present in most pasture grasses and legumes at levels no higher than 20 parts per million. In many instances 12 to 15 parts per million is as high as can be attained on a sustained basis. A deficiency condition exists in cattle and in sheep when the copper level of pastures falls below 5 parts per million and a level of 3 parts per million will produce characteristic copper deficiency symptoms. A very slight increase in feed supply of copper results in rapid response on the part of animals on a deficiency feed primarily because of the release of the stored, unutilized iron.

Whether or not a naturally occurring iron deficiency exists in animals, except in baby pigs, has been a question debated by many nutritionists. Although on a practical basis we have obtained rapid response to iron supplementation and for this reason, recommend the inclusion of some iron in mineral supplements, we are not in a position to state flatly that iron deficiency as such exists under most common circumstances. Since in many areas of the world, and in this country, animals are subjected to attacks by internal and external parasites with comparatively heavy hemorrhage, the need for iron may exceed the level in the diet and consequently a supplement of iron will give good response when animals are suffering from this combination of circumstances.

Dr. Cunha will discuss with you the problem of zinc deficiency as it exists in swine and suffice it to mention here that there is a zinc requirement which must be met in all animals. In all but the pig and in poultry, zinc deficiency is unlikely to occur because the feeds normally used by these animals, and particularly pasture, contains a fair supply of zinc.

In table 4, there are given some values for iodine, manganese, sulfur, and magnesium. Ordinarily, we recommend that iodine be included as iodized salt and be made available to pregnant animals during the last part of gestation. A question frequently is raised as to the effect of surplus or excess iodine and the older literature indicated a hazard in terms of reproductive failure. There has been comparatively little

TABLE 4

Iodine, manganese, sulfur, and magnesium: Dietary requirements, by type of animal

Type	*Iodine*	*Manganese*	*Sulfur*	*Magnesium*
	Micrograms per day	Ppm[1]	Percent	Percent
Dairy cattle	400-800	15-30	0.5	0.05
Beef cattle	200-400	15-30	.5	.05
Sheep	50-100	15-30	.5	.05
Swine	80-160	30-40	.5	.05

[1]Ppm=parts per million.

research on this subject in the last 20 to 25 years and some question has been raised as to whether excess iodine will be hazardous since the animal body is very efficient at eliminating an excess of this element.

Manganese has been closely related to calcium and phosphorus metabolism since the early work in perosis of chickens. Fifty parts per million of manganese in the diet appears to be quite adequate in meeting the needs of poultry, and certainly this value is high as regards the requirements for other livestock. It is probable that the manganese requirement of swine and of cattle and sheep is very low. Experimental work carried out recently indicates that levels as low as from 1 to 3 parts per million of manganese may be adequate for the minimum requirement of manganese in swine. Critical studies of manganese requirement have not been conducted with cattle and with sheep but it appears that a level of 15 parts per million in the diet will adequately meet the minimum requirements. In some parts of the world manganese toxicity may be a problem and although the experimental evidence for this is not clear cut, values in excess of 2,500 parts per million of manganese in forage would suggest this as a cause of nutritional difficulties.

Requirements

Most pastures and feeds contain adequate sulfur to meet the requirements of livestock. However, it has been pointed out by the work in Australia, and more recently by other investigations that sulfur may be a limiting factor in the

ruminant digestion. It is probable that on the order of from 0.3 to 0.5 percent of sulfur in the diet will provide for best ruminant digestion of roughage feeds. Many diets do not contain this level of sulfur and the use of sulfate-salts in mineral supplements has added justification because of this requirement.

The requirement of plants for magnesium has led many to assume that adequate magnesium will be present to meet the requirements of animals that depend on roughages or on diets made up largely of plant products. Certainly magnesium deficiency does not appear to be a common occurrence in any species except cattle. In cattle, the occurrence of grass tetany has led to the use of magnesium supplements, since it is known that with grass tetany blood magnesium drops to a low level. In those areas where this condition develops as it does on lush, young cereals or on magnesium low hay, use of a magnesium supplement in the mineral portion of the diet or the use of fertilizer, such as dolomite, may seem to be justified and a beneficial practice. This would appear to be a rather specialized situation in various parts of the world and can hardly be made a generalized recommendation.

There are many mineral mixtures which have been prepared both for general use and for specialized use. Some such mineral mixtures are given in Florida Bulletin 513. These mixtures have been very successful in deficiency areas of this country. The National Research Council bulletins have also recommended levels of minerals for livestock.

References

1. Minerals for Dairy and Beef Cattle—Fla. Agr. Expt. Station Bull. 513R. Jan. 1957. R.B. Becker, P.T. Dix Arnold, W.G. Kirk, George K. Davis and R.W. Kidder.
2. Nutrient Requirements of Domestic Animals.
   Number II Nutrient Requirements for Swine. 1953.
   Number III Nutrient Requirements for Dairy Cattle. 1956.
   Number IV Nutrient Requirements for Beef Cattle. 1958
   Number V Nutrient Requirements for Sheep. 1957.
   National Research Publications 295, 464, 579, and 504.
3. Trace Elements in Human and Animal Nutrition. E.J. Underwood, Academic Press, New York. 1956.
4. Trace Elements. Edited by C.A. Lamb, O.G. Bentley and J.M. Beattie. Academic Press, New York. 1958.

Amino Acids and Vitamins

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ONE is constantly hearing the term "balanced ration" used to express a ration which promotes good growth, good feed conversion, good reproduction, etc. The dictionary defines balance in terms such as "to keep in due proportion" or "to keep in equilibrium." In an ideal case, the term "balanced ration" indicates a dietary program which is perfect from both a qualitative and a quantitative standpoint—in other words, one which would maintain the animal in optimum health. Thus, while we may take a pencil and paper and formulate a ration which we believe to be adequate in every respect, we all know that nutritional variations in the feed ingredients, effects of processing, mechanical errors in mixing, interactions between the various ingredients, and, last but by no means least, variations in the nutritive requirements of different animals, all play a part in determining whether we have a truly balanced diet. This is why we can use the term "balanced ration" only in a restricted sense—restricted by our present knowledge in the field of nutrition.

Although synthetic diets have proved invaluable in determining both the qualitative and quantitative requirements for vitamins, amino acids, and fatty acids, it is becoming increasingly apparent that the requirement for these specific nutrients can be altered when fed as components of a feedstuff. In other words, we might estimate the nicotinic acid requirement of an experimental animal

using a purified diet, but when we try to apply this knowledge to a study with the same animal, using in this case a diet made up of natural feedstuffs, we might find a different picture entirely.

It is not known to what extent vitamin antagonists, or antivitamins, exist in various feed ingredients except, of course, for dicumarin, which occurs in spoiled sweetclover hay and causes vitamin K deficiency in cattle that eat it. Of course some of the drugs now being added to feeds may alter vitamin requirements but, again, little is known about this either.

Swine production in this country is changing at a rapid rate. It seems only a short time ago that the various experiment stations recommended a simple mixture of corn and tankage for the growing pig. Recognition that other feed ingredients could be substituted with equally good or better results occurred with the development of the well-known Wisconsin trinity mixture. This was composed of two parts tankage, one part linseed oilmeal, and one part alfalfa.

Vitamin B Needs

Within the past 15 years the rapid development of the soybean processing industry has made possible some fundamental changes in feed formulation.

Along with these developments, fundamental nutrition studies were uncovering new growth and reproduction factors which often found their way into commercial swine feeds. However, 15 years ago the importance of adding small quantities of certain of the B vitamins was certainly not recognized.

Under practical feeding conditions in the United States, the diet of the pig is made up largely of corn, a condition which has prevailed for a great many years. Hart and McCollum, in 1914, were among the first to study the nutritional requirements of swine with special emphasis on corn. These investigators early recognized that pigs could not be raised on corn alone, but grew well when their feed was supplemented with minerals and feedstuffs high in protein. A few other studies were reported, but

no particular studies were designed to study the needs of swine for vitamins of the B group until work was undertaken by Chick and associates of England, and Hughes of California.

Niacin Deficiency

About the time studies were showing that the rat was apparently not a suitable animal for the investigation of the pellagra-preventive and blacktongue-preventive factors which appeared to be identical, the English workers at Cambridge turned to the pig. Modified Goldberger-Wheeler diets were used and in general they found that one or more substances were lacking and that the deficiency was in the B-complex rather than in protein. Typical findings in addition to diarrhoea and loss of appetite was the presence, upon autopsy, of a diffuse cellular inflammation of the mucous membrane of the cecum and large colon which was covered with a fibrinous adherent membrane. In a subsequent paper, they reported that nicotinic acid both prevented and cured the deficiency symptoms. In view of this work and in addition knowing that corn is the most common ingredient in swine feeds, it seemed logical to us that pig pellagra might occur under practical farm conditions.

In our experimental studies of niacin deficiency, we used weanling pigs weighing approximately 25 pounds. The rations used consisted of a mixture of corn, soybean oilmeal, and minerals to which were added all of the known water and fat soluble vitamins except niacin. Thus, the experimental ration was not devoid of niacin but contained amounts lower than the animals' requirement. The first symptoms of niacin deficiency may occur within 2 weeks after the animals are placed on the experiment. Pigs with niacin deficiency will show lowered appetite, poor growth, and a rough hair coat. However, the most important and the most characteristic symptom of deficiency is the presence of diarrhoea. Niacin deficiency produces some striking changes in the large intestine. We usually find that the intestinal walls become thickened and inflamed and show definite necrotic areas.

Level of protein plays an important part in niacin deficiency. With levels of protein of 18 percent or more, we were unable to produce niacin deficiency in the pig. However, with protein levels of 15 percent and lower, severe niacin deficiency was produced. This, of course, is due to sparing action of the amino-acid tryptophan on the niacin requirement. This niacin-tryptophan interrelationship cannot be overemphasized since the various protein concentrates used in making up a commercial supplement may vary quite considerably in tryptophan content (table 1).

TABLE 1

Tryptophan content of several protein concentrates

Ingredient	*No. samples analysed*	*Avg. tryptophan*
		Percent
Meat and bone scrap (50%)	17	0.24
Tankage (60%)	12	.46
Soybean meal (44%)	20	.56

Recent work at Illinois by Dr. Johnson's group has shown that the niacin requirement of the baby pig fed a synthetic milk diet is approximately 10 mg./lb. when the tryptophan content of the ration is 0.19 percent. Since an average swine ration of 15 percent protein containing mixed protein concentrates and corn would have a tryptophan content of approximately 0.1 percent, it can be seen that the niacin requirement would be considerably higher than 10 mg./lb. of feed.

Another factor in the niacin picture which has not received the attention it deserves is based on recent results by English workers. These results indicate that almost all of the niacin present in corn occurs in a "bound" form, and that this "bound" niacin is not available to the pig or chick. Moreover, the conventional microbiological assay for this vitamin does not give a true picture of the avail-

able niacin since it measures both the "bound" and free forms. Thus, if corn contains 10 milligrams of niacin per pound by assay, we must assume that only from 2 to 4 milligrams represents the amount available to the pig. At present nothing is known concerning the presence or absence of "bound" niacin in such feedstuffs as soybean oilmeal, cottonseed oilmeal, or packinghouse byproducts. However, we do know that synthetic niacin is entirely available to the animal, and, in view of its low cost, is usually added as a supplement to swine rations by feed manufacturers.

Pantothenic Acid

Most grains and animal byproducts, such as meat and bone scrap and tankage, are rather low sources of this vitamin. While niacin deficiency shows up rapidly in the young pig—a matter of 2 weeks—typical symptoms of pantothenic acid deficiency do not show up experimentally for 6 to 10 weeks. The rations we used to produce a deficiency of this vitamin were composed principally of corn, soybean oilmeal, and minerals fortified with water and fat-soluble vitamins.

Experimentally produced pantothenic acid deficiency seems to follow a definite pattern. At about the second week a profuse diarrhoea is noted which lasts for approximately 2 weeks. This is followed by the appearance of locomotor incoordination sometimes called "goose stepping." In some cases the incoordination becomes so severe that the animals are completely paralyzed in the hind quarters. This incoordination is caused by a degeneration of the sciatic nerve.

In some recent work with pantothenic acid deficiency, we have found that just as in the case of niacin deficiency the level of protein in the ration is related to the severity of the deficiency symptoms. We were able to produce severe deficiency symptoms in a ration containing 14 percent protein and only a slightly lowered growth rate when the protein level was 18 percent. Both rations contained identical amounts of pantothenic acid.

In this connection recent work with the rat has shown that there is an interrelationship between pantothenic acid and the amino acid methionine. In other words, when pantothenic acid was absent from the diet the animals responded to

increasing percentages of dietary methionine. Thus, when the pantothenic acid content of the diet was low, the methionine requirement for growth was increased.

An important function of pantothenic acid is concerned with antibody formation. Animals deficient in this vitamin are unable to build circulating antibodies in the blood stream, and so are easier prey for disease. As a matter of fact, the animal's ability to form antibodies is impaired even before any other signs of deficiency are noted. This is important since only a marginal deficiency of this vitamin causes an effect on antibody production.

Multiple B Vitamin Deficiencies

The fact that deficiencies of niacin and pantothenic acid and riboflavin could be produced experimentally on diets of natural feedstuffs led us to investigate the possibilities of vitamin supplementation of practical swine rations. The results of this work indicated that rations containing corn, oats, soybean oilmeal, meat meal, alfalfa, and minerals could be markedly benefited by the addition of niacin, calcium pantothenate, and riboflavin. This work was also confirmed by workers at other stations.

In view of the above results, it seemed likely that B vitamin deficiencies were occurring in farm-raised pigs and were perhaps diagnosed as being of infectious origin. The results of this type of clinical study were reported by us in Technical Bulletin No. 211 of the Michigan Agricultural Experiment Station. In this study, farm-raised pigs showing diarrhoea, poor thrift, absence of appreciable fever, as well as having a history of being fed on a low-protein diet, were examined carefully to determine the cause of this type of enteritis. Such pigs weighing around 20 to 40 pounds were found in herds where the healthy pigs weighed 60 pounds or more. One pig from each of the 11 groups studied was autopsied. Lesions were located chiefly in the large intestines which were thickened, and pellets of fecal material and exudate remained attached. Edema and areas of congestion could also be observed.

Because of poor appetites, injections of substantial quantities of the B vitamins were given intraperitoneally. Doses of

50 milligrams thiamine, 50 milligrams riboflavin, 250 milligrams calcium pantothenate, 250 milligrams niacin, and 10 milligrams pyridoxine were used. In addition a 19 percent-protein ration supplemented with liberal amounts of the same vitamins used for the intraperitoneal injections was fed. The period of treatment varied from 30 to 40 days and resulted in the complete recovery of approximately 80 percent of the animals treated.

The results of these experiments demonstrate that a nutritional type of enteritis does occur under practical feeding conditions involving a multiple B vitamin deficiency. However, niacin and pantothenic acid appear to be particularly involved.

B Vitamin Fortification

In view of all the recent work showing that the pig's requirement for protein is lower than previously believed, it is particularly important not to lose sight of B vitamin fortification. The feed manufacturer must remember that in all of the published work on protein requirement, the rations used were adequately fortified with niacin, pantothenic acid and riboflavin. The successful use of lower protein rations depends not only on the use of well-balanced protein concentrates but also on the presence of adequate levels of B vitamins.

Perhaps one of the most important results of the past 15 years of research on B vitamins has been the realization that with adequate B vitamin levels in the ration, we can lower the amount of protein in the ration and still get good growth and feed conversion.

Today it is common for feed manufacturers to supplement their swine feeds with B vitamins. The vitamins usually added are nicotinic acid, calcium pantothenate, and riboflavin.

Amino Acid Supplementation

The value of amino acid supplementation of practical, well-balanced swine rations is difficult to demonstrate since our present-day soybean oilmeal appears to satisfy the animals' requirement quite well. However, certain diets of natural feed ingredients could be constructed which would benefit from the addition of an amino acid. For example, it has been demonstrated that a diet composed of corn meal, and bone

meal is very deficient in tryptophan. In another case, diets made up largely of wheat might benefit from the addition of lysine. Nevertheless, it must be admitted that there is very little information available on the value of supplementing well balanced swine rations with amino acids.

Certainly, the problems encountered in amino acid supplementation are complex and this probably accounts for the inconsistent results obtained by many workers. This is probably due to the fact that amino acids need to be fed not only at the right level, but also in the correct proportion to each other.

Thus, on the basis of present knowledge, there is little information available which would allow one to make recommendations regarding amino acid supplementation of a modern ration. However, it has been this writer's experience, as well as the experiences of others, that the very high protein quality of our present-day soybean oilmeal may make it unnecessary to consider amino acid supplementation, especially when the grain portion of the ration is composed of corn.

RUMINANT NUTRITION

Since this portion of the program will be covered in some detail by other presentations, only a brief account of some of the more recent advances will be mentioned.

Vitamins

The ruminant's ability to synthesize vitamins of the B complex by virtue of its unique fermentation capacity is well known. Thus, one is left with the fat soluble vitamins A, D, and E. With respect to Vitamin D, recent work in Holland, England, and the U. S. A. has indicated very wide ranges of vitamin D activity in roughages. It is interesting that in all three of these studies carried out with different assay techniques, and with samples taken from different agricultural systems, the general conclusions are similar; namely, that it is unsafe to conclude that an individual sample of hay—regardless of its known period or intensity of irradiation—will be a particularly rich source of vitamin D activity. The reasons for the variations observed have still to be worked out.

Vitamin A has received much attention, particulary during

the recent drouth in the southwestern part of the U.S. However, results published from the Oklahoma Experiment Station in 1955 have demonstrated that beef cows which have had access to green pasture during the summer may store sufficient reserves of Vitamin A in the liver to last through a gestation and at least the first 3 months of lactation.

Protein Nutrition

Cattle are not particularly sensitive to quality of protein or amino acid balance since, under usual feed conditions, missing amino acids can be synthesized in the rumen. Research has shown that cottonseed meal, linseed meal, and soybean meal are equal in feeding value on a protein equivalent basis.

The past 15 years have seen a very large amount of work carried out with urea in ruminant feeding, and space does not permit any detailed discussion of this field except to say that it is widely used today in commercial beef and cattle supplements. Generally, urea is used to replace up to one-third of the protein requirement for cattle. However, a number of successful experiments have been reported where 50 percent of the total nitrogen of the feed was represented by urea nitrogen. It would, thus, seem that when cattle rations are properly balanced with respect to energy and minerals, urea can play an important part of the total nitrogen requirement.

New Concepts in Swine Feeding

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THERE have been many new developments and trends in swine feeding during the last few years. New findings in swine nutrition have made it possible to greatly increase the efficiency and rate of swine production. This report will attempt to briefly summarize these new trends and to correlate them with an equally brief appraisal of the status of present knowledge.

Confinement Feeding

The trend in the United States is toward confinement feeding of pigs in concrete, and to a small extent in dirt, dry lots (1). At the present time an estimated 30 to 40 percent of all pigs are being finished in confinement. It is estimated that in 5 years this may increase to 60 percent and to at least 75 percent in 10 years. There are some who estimate that even as high as 90 percent of all pigs will be fed in confinement 10 years from now.

Confinement feeding is on the increase because, in many areas of the country, land values have increased to the point where the land will give greater returns when used to grow corn, soybeans, and other crops. In addition, the newer knowledge of swine nutrition has made it possible to compound rations which give at least as good results as fattening pigs on pasture. This is because in the early experiments on pasture vs. drylot feeding, the pasture was covering up many nutritional inadequacies of the drylot rations used then. It is

still recommended, however, that breeding animals, or those being grown out for herd replacement purposes, be kept on high quality pasture as much as possible.

A recent summary of 69 test comparisons by Dr. H.B. Guerin (2) showed that pasture saved 9 pounds of feed per 100 pounds of gain, or 16 pounds of feed per pig from weaning to market weight. The pigs on pasture gained at the rate of 1.40 pounds per day and those in drylot at 1.48 pounds daily. With feed at 3 or 4 cents per pound, this means that the 16 pounds of feed saved per pig by pasture would be worth 48 or 64 cents, respectively. Assuming that 20 pigs were run on each acre, this would be a return of $9.60 or $12.80 per acre of pasture. These low returns on pasture are one of the big reasons why an increasing number of swine producers are going to confinement feeding. It must be emphasized, however, that confinement feeding will mean that well balanced rations will need to be fed since pasture will no longer be available to cover some of the nutrient omissions of poor quality rations. It also needs to be emphasized that there are still many problems to be solved regarding confinement feeding. There are also some conditions where it may be more economical to use high quality pastures. Certain pastures which are too rough for farming, will also continue to be used for swine feeding.

More Complete Rations

The trend is toward the use of more complete rations. Under some conditions, complete rations will be best, whereas in others, free-choice feeding of corn and supplements will be superior. Many feeders are using complete ground and mixed rations for young pigs up to about 75 pounds when their nutritional needs are the most critical and when complete mixed rations have the most advantage. There is also an increasing trend toward the use of mixed rations for older pigs, especially if they are being fed in drylot and where bulk delivery facilities are available. Complete mixed rations will become more popular where automatic feed-handling systems are developed for large scale operations. Complete rations offer a better means of controlling nutrient and antibiotic intake. The pig has a fairly good ability to balance his

ration when given free access to grain and supplement. This is the reason free-choice feeding has been so popular. However, recent studies indicate that this ability is not without some faults. Dr. J. A. Hoefer (3) recently summarized a numer of trials from six experiment stations which is indicative of free-choice vs. complete rations feeding results:

	Drylot	*Pasture*
Rate of gain:		
Complete ration	1.54	1.49
Free-choice feeding	1.49	1.38
Feed per 100 pounds gain:		
Complete ration	344	327
Free-choice feeding	334	327

The economics of the gains are usually in favor of free-choice feeding because of the extra cost of grinding and mixing. Thus, one needs to balance the cost of grinding and mixing against the difference in rate of gain and feed efficiency, and the inefficiency of overeating or undereating of the protein supplement which may occur. While free-choice feeding will still continue to be used in the future, the trend is for the use of more complete rations. More uniformity of pigs, less runts and poor-doing animals, has usually been in favor of complete rations.

More Pelleted Feeds

The use of pelleted feeds is increasing. Indications are that pelleting of feeds is more beneficial with younger pigs than with older animals (4). This is one reason why pelleted feeds are used the most with starter and creep feeds. For older pigs, the big question is "Will the advantages derived pay for the cost of pelleting?" In some cases it may, whereas in others it may not.

The information obtained to date indicates that pelleting itself probably does not increase the nutritional value of feeds. This was indicated in North Dakota work (5) which showed that pelleting and regrinding a ration for feeding in meal form did not appreciably improve rate of gain or feed efficiency. The increased rates of gain and feed efficiency

obtained due to pelleting seems to be explained, in large part, on the basis of a large intake of total feed daily. A recent review by Dr. L.V. Curtin (4) is indicative of the present information on pelleting for the pig. He presented the following summary:

	Percentage increase in Rate of gain	Feed efficiency
1. Pelleted rations containing *barley* at North Dakota, Montana, Illinois and Idaho—10 experiments.	14	15
2. Pelleted rations containing *corn* at North Dakota, Illinois, Purdue and Michigan State—4 experiments.	4	6

The above summary indicates that the pelleting benefits are the greatest with bulky feeds such as barley. The North Dakota work (5) would seem to indicate a definite advantage for pelleting barley rations. More studies are needed on the value of pelleting corn rations for pigs from 25 to 200 pounds in weight. In many respects, the many questions concerning the value of pelleting still remain unanswered. Undoubtedly a big determining factor on how much pelleting will increase in the future will depend on engineering developments which might reduce the cost of pelleting substantially. The demand for pelleted feeds, however, has increased to the point where most feed manufacturers offer their feeds in either the meal or the pellet form.

Earlier Weaning

The trend is toward earlier weaning of pigs. Many swine producers now have the nutritional know-how and management facilities to wean at 5—6 weeks of age instead of the customary 8 weeks through the use of high quality starter feeds. A few highly specialized producers are weaning pigs at 3—4 weeks of age. However, it must be emphasized that the earlier the swine producer weans his pigs, the more know-how, facilities, and well-trained personnel will be needed to do it successfully. The swine producer who lacks these tools

and skills should go into the program slowly, and gradually lessen the time the pigs are kept on the sow in proportion to the success he is experiencing. The degree of early weaning should also be in line with economic considerations, and should be practiced to the extent that an economic advantage is realized. More studies are needed to determine the effect of early weaning on the subsequent performance of the pig. The Minnesota station (6) compared 3 week and 8 week weaning weights. The pigs weighed the same at 9 weeks whether they were weaned at 3 or at 8 weeks. However, from 9 weeks to 23 weeks of age (market weight) the early weaned pigs (3 weeks) required 7 percent more feed per pound of gain and they averaged 10 percent lighter at the end of the experiment. In their subsequent studies they have failed to find the cause for the post-8-week slump of the early weaned pigs. Their results indicate that much work is needed along this line before one can make unqualified recommendations on weaning at a very early age. Although pigs have been weaned at a few days of age, the practical early limit would seem to be about 3 weeks of age and for most swine producers it would be 5 to 6 weeks. Much information is still needed to determine at which age early weaning is practical and economical. It needs to be emphasized, however, that starter feeds will increasingly serve as a substitute for the sow and especially for those which do not produce enough milk to properly nourish their litters.

Silage for Sows

Recent studies have shown that silage can be used with excellent results for sows during the gestation period. Silage feeding has been shown to cut down on feed costs and to increase litter size in certain experiments. It also tends to keep the sows from getting too fat. It must be emphasized, however, that proper supplements need to be fed along with silage for good results. Feeding silage alone will result in poor litters.

Temperature Control

Considerable data are accumulating which show that the use of some cooling system is beneficial for growing-finishing

pigs during warm weather. Iowa work (7) recently showed that pigs over 100 pounds raised in confinement dropped in daily gain and feed efficiency by 0.05 pound per day and 0.05 pound feed per pound of gain, respectively, for each degree F. of average temperature rise from 80° to 85°F. This means a decrease of 0.25 pound per day in rate of gain and 25 pounds more feed per 100 pounds of gain as the temperature increased from 80° to 85°F.

The data in table 1 show that the best gains are obtained at a temperature between 60° and 70°F. The data also show that the bigger the pig is, the poorer it does as the temperature increases. California workers (8, 9, 10) found that an increase in air temperature also increased body temperature, respiratory and pulse rate. At 96°F, a rise in the relative humidity from 30 to 94 percent produced rapid distress in pigs weighing over 200 pounds. Illinois workers (11) have shown that drafts and temperature variations cause young pigs to do poorly.

TABLE 1

Effect of ambient air temperature and mean liveweights on daily rate of gain in swine

Mean liveweight	*Air temperature—°F.*							
	40°	*50°*	*60°*	*70°*	*80°*	*90°*	*100°*	*110°*
Lbs.								
100		1.37	1.58	2.00	1.97	1.40	.39	—1.32
150	1.27	1.47	1.75	2.16	1.82	1.14	—.19	—2.60
200	1.19	1.57	1.91	2.22	1.67	.88	—.77	
250	1.10	1.67	2.08	2.14	1.51	.62	—1.36	
300	1.02	1.77	2.24	2.06	1.36	.36	—1.95	
350	.94	1.87	2.41	1.98	1.21	.10	—2.53	

It is evident that the heat regulating mechanism of the pig is rather poor. Thus, much study is indicated for the future in providing feeding facilities which will provide near optimum temperatures for best performance by the pig. Not only should this provide a means of cooling (such as sprinkler, fine-mist spray, fan, wallow, coolled air or air conditioning),

but it should also take into account warming during the cold, wet winter months, since pigs do not perform as well during cold weather. Temperature control may also affect carcass quality since Michigan workers (12, 13) have shown that the pigs fed at 40° F. environment had higher blood fat levels than those fed at 80°F. The pigs at 80°F. had thicker backfat and the primal cuts were greater at 40°F. Already there are indications that temperature also may effect nutrient needs and hormone response. Thus, temperature and humidity may be partially responsible for some of the variations in experimental results being obtained at different stations and laboratories. It is possible that in the future many pigs will be exposed to less variations in temperature than the humans taking care of them.

Multiple Farrowing

Multiple farrowing is increasing and will benefit all concerned. This practice results in more frequent farrowing throughout the year. It makes more efficient use of facilities and the labor supply available. It also aids the packer by spreading the available supply of pork throughout the year. This should result in more stable prices for producers, processors, distributors, and consumers of pork. It must be emphasized, however, that frequent farrowing will require good management and disease control practices.

Life Cycle Feeding

More attention is being paid to the different stages of the life cycle of the pig. It is important to realize that the ration fed during one period will influence the results obtained in a later period. The ration a sow receives, for example, will influence how well her pigs will survive and perform during their growth period. Likewise, the ration which pigs receive during growth will influence their ability to conceive, reproduce and lactate many months later. These statements indicate the need for long-term studies which last a whole generation or more and which delve into the interrelationship of the various stages of the life cycle of the pig on each other. It must also be realized that nutritional needs are somewhat different for each stage of the life cycle. This

needs to be considered when one compounds rations for the pig. The stages of the life cycle might be divided as follows:

1. Prebreeding period
2. Gestation period.
3. Lactation period.
4. Prestarter, starter, or creep-feeding period.
5. Growing-finishing for market.
   a. 25—50 pounds.
   b. 51—75 pounds.
   c. 76—100 pounds.
   d. 101—125 pounds.
   e. 126—200 pounds.
6. Growing—developing herd replacement animals. They should receive excellent rations to develop a normal reproductive tract. They should receive as much pasture, or its equivalent, as possible and probably should leave confinement rearing somewhere between the time they weigh 50 to 125 pounds. Studies are needed to determine if confinement feeding has any limitations or deleterious effect with respect to rearing herd replacement animals. Until this information is obtained it would be best to limit the period herd replacement animals spend on concrete feeding floors.

Feed Additives

Vitamins : The use of vitamins for supplementing rations is becoming more widespread. The vitamins most apt to be lacking in practical rations, and which are being added, are riboflavin, niacin, pantothenic acid, B 12, A and D (14, 15).

Minerals : Parakeratosis, which used to be widespread and a serious problem, is now being controlled by the use of extra zinc in the ration. Excess calcium, in some way not yet understood, increases the need for zinc. Recently, the Purdue Station (16) has shown the zinc need of the very young pig to be about 50 P.P.M.

Anemia which heretofore has caused serious losses with suckling pigs is now being treated with iron injections a few days after birth. Indications are that a second injection may

be needed especially if the pigs are not eating freely of a creep or starter ration by the time they are about 3 weeks old. Since the injectable iron compounds have been used it has been demonstrated that there is less diarrhea and that apparently the pigs resistance to other diseases is improved (17).

In the future, more attention will need to be given to proper level, balance, and interrelationships of minerals. Imbalances of minerals can lead to poor results and as yet very little is known about these mineral interrelationships.

Protein : The pig has been shown to need 10 essential amino acids during growth (14). The three essential amino acids which are apt to be low or borderline in swine rations are lysine, methionine and tryptophan. As yet, however, there is little information on the value of supplementing practical rations with amino acids. The amino acid supplementation problem is a complex one and accounts for the inconsistent results obtained by many investigators.

Antibiotics : The status of antibiotics for swine feeding was recently reviewed by the writer (14, 15). Some recent data would indicate that studies are needed, and some are under way, on antibiotic combinations, rotation of antibiotic, antibiotic-arsenical combinations, and the value of new antibiotics to determine their possible value over continuously using a single antibiotic. These studies are also needed to determine whether some of the old antibiotics may be losing some of their effectiveness because certain micro-organisms might have gradually become resistant to them. Until more of this kind of experimental information is obtained, however, the continued use of antibiotics as is presently the case is recommended. Most investigators feel that if antibiotic feeding were discontinued, that pigs not fed antibiotics would revert to the performance of preantibiotic feeding. The continued use of antibiotics and other bactericidal agents are needed to suppress disease level conditions and thus allow a high productivity rate on the farm. The problem of resistant strains of disease organisms needs to be considered and studied in long-term studies involving antibiotic and other antibacterial compounds.

Arsenicals : Arsenicals are increasingly being used in

swine feeds. They are toxic compounds when fed in excess. Thus, one needs to be careful in using them since there is a fairly narrow range between toxic levels and those needed for optimum growth and control of scours. Many feed companies are now using a combination of an arsenical and an antibiotic particularly where enteric disorders, other diseases and stress factor conditions are apt to occur.

Other Antibacterial Compounds : The nitrofurans (especially furazolidone and nitrofurazone) and a combination of streptomycin-sulfaquinoxaline have been helpful in some trials (15). More studies are needed, however, with these and other compounds to more adequately determine their role in the nutrition of the pig as well as in the control of enteric infections.

Enzymes : Studies during the past few years indicate that the newborn baby pig does not have fully developed proteolytic and amylolytic enzyme systems. This means the baby pig is lacking in certain digestive enzymes during the first few weeks of life. A critical evaluation of the experimental work to date, however, would indicate that a great deal more work needs to be done in order to fully evaluate their role in supplementing swine rations.

Hormones : The information obtained to date shows only little value in adding hormones to swine rations. More work is especially needed to determine the reason for the variable results which have been obtained with certain hormones. It is important to know why they help under certain conditions and not under others. The causes for the variable results need to be worked out before the hormone supplementation picture clears and thus makes possible more practical application of hormones in swine feeding.

Tranquilizers: This field is in its beginning stages and has not been explored sufficiently for a good analysis regarding the future potential of tranquilizers in swine feeding.

Unidentified Growth Factors

There are unidentified growth factors for the pig (14). However, very few studies have been conducted on the subject in recent years. Sources of unidentified growth factors are being used in swine rations and especially for sows during

gestation and lactation and for the young pig in starter and other feeds used up to 50 to 75 pounds in weight. These would be the stages in the life cycle when unidentified growth factors are apt to be the most helpful. They should also be supplied to herd replacement animals during their growth period (to insure development of normal reproductive tracts) since it has been shown that the ration fed during growth definitely affects the ability of the gilt to conceive, reproduce and lactate many months later (14). Unidentified growth factor needs will become more apparent as confinement feeding increases since pigs will not have access to unidentified growth factors formerly available from pasture and soil.

Summary

This review indicates that we still have many gaps in our present knowledge of swine nutrition. When one realizes that somewhere between 30 to 40 percent of all pigs farrowed die before they reach market, it is apparent that more research and information is needed to prevent these wasteful and very costly losses. A great many of these losses, however, could be prevented by good education programs to get farmers to apply the experimental information already available. The average swine producer in the United States is not doing as good a job as he should and even many of our best swine producers are not doing as good a job as might be supposed. It must also be stressed that a well balanced ration will not do the job unless it is fed in adequate amounts. There are still too many swine producers who buy carefully balanced supplements and/or complete feeds, but then fail to feed enough to their pigs.

The swine industry in the United States is becoming highly specialized. We are moving from swine feeding programs based on maximum use of pasture to programs based on confinement feeding. This will result in some need for re-evaluating nutrient requirements and to devise economical rations designed for continuous feeding on concrete. The trend toward confinement feeding and toward larger feeding units will tend to bring more automation and efficiency into swine operations. Vertical integration is starting in many areas and it will have an effect on swine production practices. The swine producer in the future

will need more training and specialization in order to successfully operate. Better feeding and nutrition, more efficient production and management practices and more meat-type hogs are musts for the future.

LITERATURE CITED

1. Cunha, T.J. 1959. Feedstuffs. March 14.
2. Guerin, H.B. 1958. Report given at University of Georgia Swine Growers Day at Athens, Georgia.
3. Holfer, J.A. 1957. Feedstuffs. November 30.
4. Curtin, L.V. 1958. The Feed Bag. 34:55. October.
5. Dinnusson, W.E. and D.W. Bolin 1958. Feedstuffs. March 15.
6. Hansen, L.E. 1959. Feedstuffs. January 3.
7. Hagen, T.E., N.H. Curry and H. Giese. 1958. Iowa Agr. Eng. Dept. Mimeo Report. Ames, Iowa.
8. Heitman, H., Jr., and E.H. Hughes. 1949. J. An. Sci. 8:171.
9. Heitman, H., Jr., E.H. Hughes and C.F. Kelly. 1951. J. An. Sci. 10:907.
10. Heitman, H., Jr., C. F. Kelly and T. E. Bond. 1958. J. An. Sci. 17:62.
11. Muehling, A.J. and A.H. Jensen. 1958. Illinois Agr. Exp. Sta. Mimeo. Urbana, Illinois.
12. Morrow, R.E., A.M. Pearson, E.P. Reineka and R.J. Deans. 1957 J. An. Sci. 16:1108.
13. Morrow, R.E., E.P. Reineke, A.M. Pearson and J.A. Hoefer. 1957. J. An. Sci. 16:1047.
14. Cunha, T.J. 1957. Swine Feeding and Nutrition (Book). Interscience Publishers, Inc. New York, New York.
15. Cunha, T.J. 1958, Proc. 6th Annual Chas. Pfizer & Co., Inc.. Research Conference.
16. Smith, W.H., M.P. Plumlee and W.M. Beeson. 1958. J. An. Sci 17:1186.
17. Hoefer, J.A. 1959. The Feed Bag. February.

New Concepts of Ruminant Nutrition

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THE new concept of ruminant nutrition goes back to the 1930's when investigators proved that microbes in the reticulo-rumen of cattle and sheep synthesized good protein from nonprotein compound for their hosts. During the early 1940's, workers at Cambridge University showed that in the ruminant, carbohydrates were converted to fatty acids (VFA) by microbes. Early investigators, including Kellner, Armsby, Haecker, and others, worked out some of the requirements of cattle used today before the new concept of ruminant nutrition was known (18).

Forage is characterized by a high proportion of celluloses and hemicelluloses which cannot be digested by the enzymes in the digestive juices secreted by ruminants, and by considerable amounts of nonprotein nitrogen compounds which are of little value until synthesized into proteins by rumen microorganisms. Fortunately, the ruminant is equipped with a spacious fermentation vat (omasum, reticulum, rumen) which is suitable for the maintenance of a large microbial population capable of digesting plant constituents and synthesizing nutrients for the host. In addition to its large size, the fermentation vat has the advantage of being located at the head of the digestive tract which gives the microbes access to the readily available nutrients consumed by the animal. This location makes possible the regurgitation of coarse roughage for chewing over again (cud chewing). Then, too, the forward

position results in making use of saliva, which is geared to aid in maintaining microbial fermentation.

Energy Relations

The expensive part of the ration of ruminants is energy because of the large amount needed for maintenance and production of meat, wool, and milk. Usually, energy is supplied more economically in the form of forages such as pasture, hay, and silage crops. This means a big job for the fermentation vat microbes since about 50 percent of the dry matter in these crops is made up of compounds that cannot be digested by the ruminant itself.

Volatile fatty acids (*VFA*): Microbial digestion of carbohydrates in ruminants results in the production of VFA, carbon dioxide, and methane. Taffeiner in 1884 found these acids in the rumen, but early workers regarded them as worthless from the standpoint of nutrition. It was not until the early 1940's that investigators in England showed that the microbial digestion of carbohydrates produced acetic, propionic, and butyric acids in the ratio of about 70, 18, 12, respectively (19). It was estimated that the VFA supplied the cow with 4572 to 5,713 cal. of available energy daily.

The concept that ruminants get most of their energy from VFA and not glucose as in the nonruminant was revolutionary as has been pointed out in several reviews (2, 3, 9). Many investigators using various methods have estimated the amounts and proportions of the VFA produced during rumen fermentation. The results of recent studies indicate that 63 percent of the energy required for maintenance is supplied by these acids (27). The estimates of investigators using various methods ranged from about 15 to 70 percent of the total digestible nutrients energy in the ration presented to the ruminant as volatile fatty acids (9).

It has been pointed out by several workers (9) that the heat increment of acetic acid is of greater magnitude than that of propionic and butyric acids. The administration of the three acids together, however, in the molar proportions of 5 : 3 : 2 produced a lower heat increment than the predicted value based on knowledge of the effects of the three individual acids (9). Rations that favour an increase in propionic and butyric

acids in the rumen ingesta may be more efficiently used.

There is overwhelming evidence that variations in the makeup of the ration as a whole, modify the amounts and molar ratios of the VFA formed (2, 3, 7, 9). A low amount of roughage in the ration of cows leads to increased proportion of propionate and a decrease in acetate. Several workers have suggested that the intermediary metabolism of the VFA, more particularly acetic acid, might be the main factor concerned with the high heat increment in the ruminant (7, 9, 16). The ration of lambs supplemented with acetic or propionic acid saved feed, while the addition of lactic acid increased body weight (3).

Up to the present time, it is possible to account for only about 50 percent of the net energy that cattle receive. Just how they obtain the rest of the energy remains a mystery. There is a possibility that the techniques used to measure VFA production in the fermentation vat may be too artificial. Attempts to make actual measurements directly over a period of time have failed so far. This problem is the most important problem facing ruminant nutrition at the present time. There is a wide variation in feed evaluation by the different systems as was pointed out by Blaxter (4), in a comparison of the evaluation systems (table 1).

TABLE 1

Estimates of the nutritive value of artificially dried immature grass and a mature grass, assessed by different systems of feed evaluation

System	*Unit*	*Dried grass, Immature*	*Rye, grass hay, mature*	*Superiority of dried grass*
				Percent
T.D.N.	Lb./100#	64.1	49.6	29
E.H.E. (Morrison)	Therms/100#	53.4	36.6	46
Kellner's S.E.	Kg./100#	56.2	32.1	75
Modified S.E. (United Kingdom)	Lb./100#	56.2	38.5	46
Food United System (Scandinavia, France, Israel)	F.U./100#	80.4	43.2	86

As was pointed out by Blaxter, all these estimates cannot be correct; yet economic and other considerations are made on the assumption that any particular one of them does, in fact, reflect the true nutritive worth of the material under consideration. When rumen scientists learn what happens in the rumen, then a reliable method of estimating the nutritive value of different roughages may be worked out.

Protein in Ruminant Nutrition

Another important unique characteristic of ruminants is the way nitrogenous compounds are handled by the microbes in the fermentation vat. Much of the protein consumed is hydrolized by bacterial enzymes to ammonia as are the non-protein nitrogenous compounds such as urea (1). The microbes use the ammonia for the synthesis of microbial protein. In order to make efficient use of ammonia, it is necessary to feed the ruminant carbohydrates such as starch and sugar, which are quickly converted to VFA that combine with the ammonia. When celluloses make up most of the carbohydrate, insufficient VFA may be produced to combine with all of the ammonia and the surplus passes through the rumen wall into the portal circulation and to the liver. The liver converts it to urea. Excessive ammonia absorption from the fermentation vat may be toxic.

A part of the urea formed is returned to the rumen in the saliva. Some investigators speculated that urea may be passed from the blood through the rumen wall into the rumen under nutritional stress (1).

The mechanism of urea excretion in ruminants differs from that observed in other mammals, indicating the presence of a physiological mechanism in the ruminant which conserves nitrogen under nutritional stress conditions. Sheep on a low nitrogen ration showed a reduction in urinary urea. Only about 50 percent of the urea injected into the sheep was recovered in the urine. Urea secretion into rumen is at least 15 times greater than urea secretion by the salivary glands. The urea secretion into the rumen occurs even under normal conditions. This recycle system for ammonia and urea to supplement feed protein appears to be geared to preserve the microbial population when the protein intake is very low.

Appreciable absorption of urea occurred from a 5 percent solution from the rumen, but none from 0.2 and 1 percent urea solutions. These data imply that little or no urea escapes from the rumen into the blood stream through the rumen wall, since the urea in the rumen usually falls below 0.5 percent. In other words, the movement of urea through the rumen wall is a one-way process.

The rumen bacteria synthesize protein from nonprotein nitrogen. A second upgrading of protein quality is brought about by the protozoa that engulf many of the bacteria and process the protein into protozoal protein. This protein has about the same biological value as bacterial protein (80 percent) but the digestibility is 91 percent as opposed to 74 percent for bacterial protein (1). The amino acid composition of microbial protein from sheep and cattle where urea was the only feed source of protein has been determined. The fairly high digestibility and biological value of microbial protein account for the ability of ruminants to get along with protein supplements of low biological value such as those high in urea.

The ability of ruminants to use urea means a saving of protein supplements such as soybean oilmeal for the feeding of poultry and swine. Usually, not more than one third of the required protein should be supplied by urea. In the early work, the role of urea in the feeding of ruminants, was obscured by the high level of protein in the ration. In the 1930's Wisconsin investigators using a low protein basal ration discovered the value of urea and ammonia salts for microbial protein synthesis (1).

Results with beef and dairy cattle show that these classes of livestock use the protein equivalent in urea about as efficiently as the protein in regular protein feeds. In the case of lambs, however, research is conflicting. Growing lambs and mature sheep, however, appear to utilize urea better than fattening lambs (1, 21).

National Research Council Requirements (NRC)

NRC requirements are supposed to be near the actual requirements and without a margin of safety (18). In ruminants, however, the requirements are guideposts to aid the feeder, because of the inadequacies of the quantitative data

upon which the requirements are based. The rationing of ruminants still requires art as well as science.

Forage Utilization

Pasture : The economical production of milk, meat, and wool by ruminants depends on plenty of roughages that fit the fermentation vat. The only method of using these crops at the peak of their nutritive power is by intensive pasturing.

During the past 10 years several investigators have worked out methods of improving the yield and utilization of pasture when the dry matter of the crops is about 75 percent digestible (24). Fertilizers are a must, along with sufficient moisture. Proper methods of grazing are imperative. This means using the proper number of good animals on the pasture and managing so that neither undergrazing or overgrazing takes place. In areas where hot, dry weather prevails, animals should be allowed to graze day and night (12). The crop should be handled in such a manner that the soil is shaded by foliage. Also, pasture plants that do well in hot, dry weather should be in the mixture. Pasture which is near the barn is difficult to surpass in terms of cost of TDN per pound. In many areas temporary pasture crops such as Sudangrass help the dairyman feed his livestock during the summer slump in permanent pastures.

Hay Crop : When pasture herbage is not available, especially during the winter in many areas, it is necessary to feed conserved forage, usually as sun-cured hay. The most important factor affecting the nutritive value of hay and silage is the state of maturity at which they are cut (17). When cut in the vegetative stage (before boot) most hay and silage crops are highly digestible. This is due to the high proportion of leaves to stems. The stems are the part of the crop that nobody wants because of their low digestibility. At the full bloom stage, hay or silage is not very nutritious. Although immature forage is more productive than more mature forage, yet improved methods will permit economical conservation without loss of nutrients in regions of unfavorable weather where needed.

Silage: In order to get away from weather losses in hay making many dairymen have adopted silage making.

Good corn silage generally contains 66 to 70 percent TDN on the dry basis. It is difficult to harvest hay crops at an early enough stage of development for them to be equal to corn silage in productive energy value. Grass silages made from mixtures high in legumes are high in protein (17). Some allowance should be made for the amount of grain in the corn silage. Corn silage is especially good for all classes of ruminants.

Appetite for Roughage

Efficient production of ruminants depends to a large degree on the amount as well as the quality of roughage consumed. Most workers have found that dairy cows consume more early-cut hay than mature hay.

New indirect techniques for estimating the dry matter intake of pasture actually grazed have shown a considerable degree of herbage selection and fairly high intake of dry matter (22).

Several investigators have shown that silages contain a factor that depresses dry matter consumption. This holds true for corn silage as well as grass silage. The factor(s) does not appear to be the amount of moisture in the silage, although the higher the moisture content of conserved silage the greater the appetite depression (17). Grass silage appears to be better adapted for dairy cattle than for beef cattle.

Utilization of Poor Roughages

Greater knowledge of the needs of rumen bacteria has resulted in more production from poor roughage (25). Corncobs, which a few years ago were considered almost worthless as a feed, have been elevated to the position of a good source of energy. In order to utilize corncobs, the ration must be amply supplied with protein, cereal grains, minerals, and some high grade roughage. Cobs, when properly supplemented, may be used as the only roughage in wintering young beef cattle or dairy cows. It is necessary to grind the cobs and mix them with palatable concentrates in order to make them acceptable to ruminants. Ground cobs have been used as part of the fattening ration of beef cattle. Cobs, fed as the only roughage to fattening beef cattle, produced greater gains than

oat straw or cottonseed hulls but less than corn silage. They may also be used in the ration of growing dairy heifers. Recent experiments showed that corncobs are equal to ordinary hay, when fed to dairy cows as most of the roughage when some good roughage is also fed.

Effect of Plane of Nutrition

Research at Beltsville with identical twins has shown the large recovery capacity of retarded animals when good feeding is restored (29). An experiment with dairy cows is in progress at Cornell University (23) to determine the effect of raising dairy heifers on different planes of energy intake to first calving on subsequent milk production and body size; milk production after the first lactation has favored the lower plane of nutrition. This is a field that needs a lot of attention.

Preparation of Feeds

Workers at the University of New Hampshire, using dairy cows, showed that fine grain mixtures were more nutritious than comparable coarse and pelleted mixtures. Ground corn had a higher nutritive value than flaked corn, but crimped oats were superior to ground oats (6). Certainly, more research is needed in this area.

Pelleting, cubing, or wafering are attracting attention at the present time. A dramatic improvement in gains of steer calves resulted from grinding and pelleting alfalfa-timothy hay as compared with the same forage chopped or long was shown at the Illinois station (table 2), (28).

TABLE 2.
Comparison of feeding timothy-alfalfa hay in baled, chopped, or pelleted form to 15 steer calves

Form in which hay was fed	*Baled (long)*	*Chopped*	*Finely ground and pelleted*
	Lb.	Lb.	Lb.
Avg. initial weight	421.00	423.00	430.00
Avg. daily gain (119 days)	.63	.62	1.73
Avg. daily feed intake	10.96	10.70	15.69
Gain per ton of feed	115.50	116.20	220.70

Pelleted feeds are especially adapted for outdoor feeding and for use as supplements for stock on pasture or range, as there is less wastage. In several experiments self-feeding of a pelleted mixture of concentrates and ground hay has been compared with self-feeding or hand-feeding the same mixture. In most trials the lambs fed pellets have gained more rapidly due to greater feed intake. Usually, however, the gains have not been economical because of the cost of pelleting (21).

The feeding of pelleted ration to dairy cows has resulted in a decline in the percentage of butterfat in milk. At the present time, hay biscuits or wafers containing long pieces of roughage are being studied. The results at the Oregon station showed that there was no significant difference between feeding hay wafers and long hay (13).

Transition of the Young to a Ruminant

The newborn ruminant is essentially a nonruminant from a functional standpoint. Also the young calf has difficulty digesting vegetable foods until 3 to 4 weeks of age (26). During this early period most of the ration should be milk or milk replacer composed primarily of milk byproducts including dried skim milk, dried buttermilk, and/or dried whey. The big problem facing the young ruminant is its conversion to a "true" ruminant with a well-developed fermentation vat. This time may vary with the rate of development of the rumen. Recent data indicate that dry matter from roughage and grain supply factors stimulate the rumen development so that when calves are 2 to 4 months of age the proportion of the size of the rumen to that of the adult cow are about equal. Also, cellulose digestibility is about the same as in the adult cow when the calf is about 2 months of age. The odor of normal rumen contents is noticeable at about 1 month of age in the calf. Several investigators throughout the world have shown that young calves that are given access to pasture herbage at 1 week of age start picking at it and by 2 months of age may be turned to very good pasture. The pasture herbage must be top quality since calves are more selective in their grazing than mature cattle.

Drug Additives

Hormones: In 1954 Burroughs (5) of the Iowa station

reported that the feeding of stilbestrol in the concentrate mixture for fattening cattle increased weight gains and feed efficiency. Since that time, a large number of research workers have reported that the feeding of 10 milligrams of diethystilbestrol per head per day to steer weighing 600 pounds or over, resulted in increasing feed lot gains of 17 percent (25). Feed saving has averaged 12 percent. Carcass grade and dressing percentage showed no significant change.

Following the highly successful use of the oral administration method, the use of subcutaneous implants was investigated. With dosages lowered so that side effects were not so pronounced, the implant method has also become widely used (25). It has been estimated that 75 percent of the fattening cattle in the United States are fed this hormone. As was pointed out by Riggs (25), no compound about which so little information was available concerning its mode of action and effects on the animal has ever had as much impact on the beef cattle industry. The use of stilbestrol in fattening lamb feeding has usually had undesirable side effects (21).

The feeding of 10-15 milligrams of stilbestrol per milking cow daily for 60 days did not affect milk production according to USDA workers at Beltsville. Workers at the Kansas station, where indentical twins were used, estimated that the hormone-fed twins were 6 percent more efficient in the production of 4 percent fat content milk. However, results at the Alabama station indicated that the feeding of stilbestrol was of no value for milk production.

Thyroprotein: Thyroxine is the active principle of thyroprotein. Many experiments have shown that when this hormone is fed properly to good cows after they have passed the peak of lactation there is increased milk production of about 15 percent. It is essential to increase grain feeding to meet the need for the increased milk production, otherwise the cows lose weight. When thyroprotein is discontinued there is an abrupt drop in milk production which may result in more feed required to produce 100 pounds of milk.

It is not advisable to continue feeding the hormone for more than 120 days and not during the first 50 days of lactation. It should not be fed during hot weather. The Purebred Cattle Association (United States) prohibits its use for cows

on official test. The Committee on Animal Nutrition of NRC (Publication No. 266, 1953) concluded, "The available data suggest no definite economic advantage of feeding thyroprotein to dairy cows under most farm conditions."

There appears to be no advantage in feeding thyroprotein to beef cattle and sheep.

Antibiotics

The antibiotics, chlortetracycline and oxytetracycline, appear to be of value in some ruminant rations (14). Many investigations have shown that chlortetracycline enhances the growth of young dairy calves when given 15 to 45 milligrams and as high as 150 milligrams per calf daily. Thirty milligrams of oxytetracycline per 100 pounds of body weight appeared to give a boost in growth rate equal to chlortetracycline. In most studies, the administration of these antibiotics reduced the incidence of scours and some of the other infectious diseases. Antibiotics supplement has the greatest value during the first 2 months of a calf's life. It is the opinion of most investigators that antibiotics supplementation is most effective as a supplement to milk replacer feeds. In most experiments with dairy cows antibiotics have failed to affect milk production.

Apparently, the oral administration of chlortetracycline at a level of 24 milligrams per 100 pounds of body weight to suckling beef calves decreased scours and increased growth (25). A summary of 32 experiments shows that feeding antibiotics at about 75 milligrams increased grain 6 percent, and produced a feed saving of 4 percent with fattening beef cattle. Antibiotics may be more valuable in commerical feedlots where they tend to reduce losses.

Tranquilizers

The use of tranquilizers as a supplement to the ration of cattle and sheep is new. The results of preliminary experiments with beef cattle and sheep have recently been reported (8). The feeding of hydroxyzine (Tran-Q) to dairy cows had no effect on milk production, body weight, or feed intake, at the Michigan station (15).

Bloat

Worldwide research during the past few years has esta-

blished that the administration of penicillin has a temporary effect in bloat prevention and that intense frothing of the rumen content is involved in bloat. The prevention of bloat by penicillin suggests that pasture bloat is associated with rumen micro-organisms. The temporary nature of bloat prevention by this antibiotic has been shown to be due to the production of a penicillinase with time after the start of penicillin feeding that destroys penicillin.

Workers in New Zealand (10) and at the Iowa station (11) have demonstrated that spraying "bloaty" pasture with oils, placing oils in water tanks, or adding oils to rations appear to aid in bloat prevention. Thus far, however, the use of oils so that each animal gets about 2 ounces daily is not very practical. Nevertheless, the progress during the past few years is encouraging. Bloat and the fear of bloat prevents maximum use of some of the best pastures.

REFERENCES

1. Anon. *Digest of Research on Urea and Ruminant Nutrition.* E.I. Du Pont De Nemours and Company (Inc.), Wilmington 98, Delaware. 1958.
2. Armstrong, D.G. and K.L. Blaxter. The utilization of acetic, propionic and butyric acids by fattening sheep. *Brit. J. Nutrition 11:*413. 1957.
3. Bentley, O.G., R.R. Johnson, G.W. Royal *et al.* Studies on the feeding value of acetic, propionic, and lactic acids with growing fattening lambs. *Ohio Agr. Expt. Res. Bul.* 774. 1956.
4. Blaxter, K.L. The nutritive value of feeds as sources of of energy: A review. J. Dairy Sci. *39:*1396. 1956.
5. Burroughs, W., C.C. Culbertson, J. Kastelic, E. Cheng, and W.H. Hale. The effects of trace amounts of diethylstilbestrol in rations of fattening steers. Science *120:*66. 1954.
6. Colovos, N.F., H.A. Keener, H.A. Davis, K.S. Morrown, and K.S. Gibson. The effect of texture on the nutritive value of concentrates for dairy cattle. *New Hampshire Agr. Expt. Sta. Bul.* 419. 1955.
7. Elliot, J.M. and J.K. Loosli. Relationship of milk production efficiency to the relative proportions of the rumen volatile fatty acids. *J. Dairy Sci. 42:*843. 1959.
8. Hale, W.H. and W.G. Huber. Tranquilizers in animal nutrition and veterinary medicine. *Proc. Sixth Ann. Research Conf.* Chas. Phizer and Co. Terre Huate, Indiana, p. 101. 1958.
9. Huffman, C.F. Adequacy of dairy feeding input-output research data from the viewpoint of the nutritionist. *Nutritional and*

Economic Aspects of Feed Utilization by Dairy Cows. Iowa State College Press, Ames, Iowa, p. 89. 1958.

10. Johns, A.T. Bloat. *Vet. Reviews and Annotations 2:*107. 1956.
11. Johnson, R.H., L.B. Brown, N.L. Jacobson, and P.G. Homeyer. Effectiveness and practicality of some oils, penicillin, decly alcohol, and lecithin in the control of alfalfa bloat. *J. Animal Sci. 16:*1048. 1957.
12. Johnston, J.E. The effects of high temperature on milk production. *J. Heredity 49:*65. 1958.
13. Jones, I.R., B.F. Magill and R.G. Peterson. Baled, wafered and pelleted hay. *Ore. Agr. Expt. Sta.* (unnumbered) 10 pp. 1958.
14. Lassiter, C.A. Antibiotics as growth stimulents for dairy calves: A review. *J. Dairy Sci. 38:*1102. 1955.
15. Lassiter, C.A., C.F. Huffman, and C.W. Duncan. Effect of a tranquilizer (Hydroxyzine) on the performance of milking cows. *J. Animal Sci. 17:*1222. 1958.
16. McClymont, G.L. Specific dynamic action of acetic acid and heat increment of feeding in ruminants. *Austral. J. Sci. Res. Series B. 1:*93. 1952.
17. Moore, L.A. Influence of forage quality on feed efficiency. *Nutritional and Economic Aspects of Feed Utilization by Dairy Cows,* Iowa State College Press, Ames, Iowa. p. 152. 1958.
18. National Research Council. Nutrients requirements of domestic animals. Number III. Nutrient requirements of dairy cattle. Rev. 1956, Publication 464. Number IV. Nutrition requirements of beef cattle. Rev. 1958, Publication 579. Number V. Nutrient requirements of sheep. Rev. 1957, Publication 504.
19. Phillipson, A.T. The role of the microflora of the alimentary tract of herbivora with special reference to ruminants. III. Fermentation in the alimentary tract and the metabolism of the derived fatty acids. *Nutrition Abstr. and Rev. 17:*12. 1947-1948.
20. Phillipson, A.T. The fatty acids present in the rumen of lambs fed on a flaked maize ration. *Brit. J. Nutrition 6:*190. 1952.
21. Pope, A.L. Fifty years of progress in sheep nutrition. *J. Animal Sci. 17:*981. 1958.
22. Reid, J.T. and W.K. Kennedy. Measurement of forage intake by grazing animals. *Proc. Seventh International Grassland Congress,* New Zealand. p. 116. 1956.
23. Reid, J.T., J.K. Loosli, K.L. Turk, S.A. Asdell and S.E. Smith. Progress report on a study of the effect of plane of early nutrition upon reproductive and productive performance of Holstein cattle. *J. Dairy Sci. 40:*610, 1957.
24. Reid, J.T. Pasture evaluation in relation to feed efficiency. *Nutritional and Economic Aspect of Feed Utilization by Dairy Cows.* Iowa State College Press, Ames, Iowa. p. 135. 1958.
25. Riggs, J.K. Fifty years of progress in beef cattle nutrition. *J. Animal Sci. 17:*981. 1958.
26. Roy, J.H.B. The nutrition of the early weaned dairy calf: A

review. *Dairy Sci. Abstr. 20:*2. 1958.

27. Stewart, W.E., D.G. Stewart and L.H. Schultz. Rates of volatile fatty acid production in the bovine rumen. *J. Animal Sci. 17:*723. 1958.
28. Webb, R.J., G.F. Cmarik and H.A. Cate. Comparison of feeding three forages as baled hay, chopped hay, hay pellets and silage to steer calves. *J. Animal Sci. 16:*1057. 1957.
29. Winchester, C.F. and N.R. Ellis. Delayed growth of beef cattle. *U.S.D.A. Tech. Bul.* 1159. 1957.

Current Status of Nutritional Requirements of Poultry

By H. R. BIRD
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EFFICIENCY of production of poultry and eggs has been increased by developing better strains of birds, better feeds, better methods of disease control, and better management. A major factor in developing better feeds was the measurement of the nutritional requirements of poultry. What nutrients are needed by poultry? How much of each is needed under different conditions in different stages of the life cycle? How may these quantities of the required nutrients be furnished at the least cost?

Publication 301 of the National Academy of Sciences, National Research Council, entitled "Nutrient Requirements for Poultry," presents figures based on all of the available published information, as collected and interpreted by a committee of 5 members. This report is now being revised; however, only a few of the figures are likely to be changed.

Vitamins and Minerals

The figures in this report are all estimates of requirements. They do not include any margins of safety to cover destruction of vitamins which may occur during storage of feed. It is the usual practice in the feed industry to allow for some destruction of vitamins and for other exigencies by using levels of vitamins which exceed the recommendations by at least 20 percent, and sometimes by more than 100 percent.

The young chicken's quantitative requirements for calcium phosphorus, sodium chloride, potassium, manganese, iodine,

magnesium, iron, and copper are reasonably well established. Research of the past few years has established the chicken's need for zinc, molybdenum, and selenium, at least under some experimental conditions. When the quantitative needs for a mineral element have been established, there is usually no important economic problem involved in meeting the requirement. This is especially true of the trace elements. It costs only 2 cents to provide manganese fortification for a ton of feed. Phosphorus is the most costly mineral element; and in the past, it was sometimes difficult to obtain enough for livestock feeds. High phosphate deposits that are low in the toxic element, fluorine, are scarce in this country. This problem has been solved in part by importation, in part by defluorination of native phosphate rock, and in part by use of relatively low phosphate materials which are also low in fluorine.

The NRC paper gives the requirements of chickens for 12 vitamins, and summarizes available information on the vitamin requirements of turkeys and ducks. It does not give requirement figures for all of theoritamine. Chickens and other poultry make their own vitamin C. They need vitamin E in the diet, but the quantity needed is influenced so much by the composition of the diet that any single figure is likely to be more wrong than right. They also need some nutrients which are yet unidentified. The rapid progress in poultry nutrition research might tempt us to think we know everything about feeding poultry, but one can put together a diet which supplies the whole long list of required minerals, vitamins, and amino acids and then obtain improved early growth and reproduction by adding fish products, dried whey, dehydrated green feed, or certain fermentation products. Some of the unknowns are probably mineral elements, but some almost certainly are organic and therefore vitaminlike.

Chickens grow and produce on diets which do not contain sources of these unknown factors, but they grow faster and produce eggs that hatch better if the factors are supplied. Therefore fish products, dried whey, dehydrated green feed, and fermentation byproducts have special value in feeds for young growing birds and for breeders. The requirement for these factors is influenced by the bacterial population of the digestive tract and probably by other characteristics of the environment. These effects make it difficult to study these unknown factors;

the difficulty is increased by the fact that these factors do not make the difference between life and death but only between good growth and better growth, or between good hatchability and better hatchability. It will take a few years to find out what these factors are and how much of each is needed.

One of the miracles of modern science that is largely unappreciated by the general public is the production of vitamins for animal feeding by fermentation and by chemical synthesis. A few years ago the cost of poultry feeds was greatly influenced by the relatively high cost of cod liver oil to supply vitamins A and D, dried skim milk to supply riboflavin and pantothenic acid, and animal byproducts to supply vitamin B 12. Now, all of these vitamins as well as nicotinic acid, choline, and vitamins E and K are supplied in synthetic form or in high-potency concentrates derived from fermentation, and they add only a few cents to the cost of 100 pounds of feed.

All the known vitamins can be manufactured at relatively low cost. They can be transported easily because they have such high biologic potency per unit of weight. There would seem to be little reason for vitamin deficiencies in man or beast, anywhere in the world. One consequence of the low cost of vitamins is over-fortification of many feeds. Recently I talked to a feed manufacturer who employs the services of a consultant to formulate his feeds. The consultant adds a margin of safety to the vitamin requirement figures reported by the NRC. Then the manufacturer adds another margin of safety to the consultant's figures. Such over-fortification is quite unnecessary and does not increase the value of the feed, but it is also relatively harmless, because of the low cost of vitamins.

Protein, Energy, Amino Acids

So much for minerals and vitamins. The remaining essential components of the diet are protein and energy. The current methods of meeting the requirements for protein and energy are much less satisfactory than are the methods of meeting the requirements for minerals and vitamins. Based on recent wholesale prices in the central United States, the ingredient cost of the feed of laying hens can be partitioned as follows: 60 percent for energy, 33 percent for protein, 4 percent for minerals, and 3 percent for vitamins.

The problems of determining requirements for protein and energy are complicated enough. The problems of meeting these requirements are still more complicated. They range from grain surpluses and obesity in some parts of the world to low-calorie human diets and nothing left for animal industry in other areas. Perhaps some day chemistry will solve these problems by developing low-cost sources of food energy and protein. However, there seems to be no hope of such a development in the near future. We will have to depend on better methods of producing and distributing feed and food crops, the development of new products and byproducts which supply energy and protein, and more efficient utilization of energy and protein by food-producing animals.

The achievement of these new methods, new products, and new efficiencies will require the efforts of many people besides those who do research in chemistry and nutrition. It will require—in alphabetical order—bankers, business men, engineers, farmers, salesmen, statesman and teachers, and this list is not complete.

The NRC publication gives protein requirements of chickens of several ages and of turkeys and ducks. These figures are not likely to be changed in the revised report, but a qualifying statement will be added explaining the relation between energy and protein levels. There are probably several factors that influence the quantity of feed eaten by a chicken; certainly one of the most important is the concentration of Calories in the feed. The more Calories there are per pound, the less feed will be eaten. The less feed the chicken eats, the more protein there should be in each pound. Therefore, the greater the concentration of Calories, the greater should be the concentration of protein. This relation is especially important for young growing chickens and turkeys.

During the past several years there has been a trend in this country toward higher concentrations of energy in poultry feeds. The effect of this trend is to increase the percentage of protein which is required for best results. On the other hand, the accumulating knowledge of the amino acid requirements of chickens and the amino acid contents of feed ingredients makes it possible to put together a feed of better protein quality than

those we used formerly. The effect of this development is to decrease protein requirements.

As might be expected, these conflicting effects are causing some confusion among those who formulate poultry feeds and who have to decide on what level of protein to use. Eventually the new information will be organized and properly interpreted and the confusion will diminish. At this moment, feed formulators appear to be under the influence of the high energy-high protein trend and do not appreciate what lower levels of better-quality protein can do. Protein levels in all types of feeds are often higher than those recommended in the NRC report, and this is especially true of feeds for young birds. A number of papers have been published which show that it is possible with protein of superior quality to feed less than the recommended levels. This work is likely to find important practical application in the future.

The relation of amino acids to protein quality has been mentioned. The NRC report gives the young chicken's requirement for 13 amino acids. This list is believed to be complete. The requirements for the essential amino acids are parts of the protein requirement; and like the protein requirement, they vary with the level of dietary energy. They also vary with the level of dietary protein.

All that is required of a high-quality protein is that it supply all thirteen of the necessary amino acids in approximately the right proportions, plus some additional amino acid nitrogen. And all that is required of the feed formulator who deals with this problem is that he balance 13 amino acids with each other and with total protein and energy.

Energy requirements of poultry are not given in the NRC report. They have not been studied extensively. In practice, the feed formulator attempts to select ingredients that will provide energy as economically as possible and to put these ingredients together in a mixture that is balanced with respect to all nutrients and that will induce the highest possible energy intake.

There is still much to learn about the ideal balances among the essential amino acids, total protein, and energy. In the next few years, the study of these balances will probably be the nutritionists' greatest contribution to further improvements

in the efficiency of utilization of energy and protein and, therefore, of feed.

Although the chemist is not likely, in the foreseeable future, to provide a complete solution to the energy problem or the protein problem as he did for vitamins, he is contributing to the solution of the protein problem by synthesis of the essential amino acids. Synthetic methionine and its hydroxy analogue, which the chicken converts to methionine, are now widely used in poultry feeds, and there is interest in synthetic glycine and lysine. The problems encountered here are different from those involved in the use of synthetic vitamins. A ton of broiler feed has enough riboflavin if it contains 2.6 grams, but it needs 9 pounds of methionine. Obviously, it is more difficult to synthesize and sell a compound that is required by the pound than one that is required by the gram. Fortunately, most diets contain almost enough methionine in the protein and need only a little extra of the synthetic amino acid. A ton of typical broiler mash might contain 8 pounds of methionine in its protein and need only 1 pound of synthetic. Without synthetic amino acids, the formulation of feeds involves the juggling of several protein supplements in an attempt to get a desired amino acid combination. Synthetic amino acids which can be added individually, make it much easier to arrive at the desired combination. For this reason a very small supplement of a synthetic amino acid may have a large effect in improving a feed.

Other Ingredients

At this point you may be thinking that there are many things in feeds besides minerals, vitamins, protein, amino acids, and energy. These other ingredients are not nutrients, but they may have a profound effect on the manner in which nutrients are used. An antibiotic or arsenical helps the chicken by decreasing the competition he gets from the microorganisms in his digestive tract and therefore improves his efficiency of utilization of feed. A coccidiostat or other disease-preventing drug helps to maintain a high level of health and therefore a high level of efficiency of feed utilization. An estrogenic hormone increases the conversion of carbohydrate to fat and therefore improves the finish of the dressed carcass. An enzyme

may improve utilization of some components of the diet.

Our information on nutrient requirements is probably more complete for the young chicken than for any other animal, including man. But we should remember that there are still many gaps in our information on the requirements of mature chickens and of other species of poultry. We should remember also that nearly all our information on nutritive requirements applies to healthy birds in a more or less standard environment. We have very little exact information on nutrient requirements in disease or in changing environments. Furthermore, the problems of satisfying nutrient requirements change continually as the economic climate changes, as new products become available, and as new information on requirements becomes available.

Past progress in our knowledge of poultry nutrition has brought results that can be measured in terms of the amount of labour required to purchase a dozen eggs or a pound of poultry. To buy a dozen eggs, an average American workingman worked 48 minutes in 1930, 25 minutes in 1950, and only 18 minutes in 1956. To buy a pound of chicken, he worked 24 minutes in 1950, but only 15 minutes in 1956. There are still questions waiting to be answered, and there is still further progress to be made.

Summarization of New Concepts

By H. R. BIRD
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SEVERAL new concepts which play an important part in the formulation and manufacture of poultry feeds have been discussed. These may be summarized as follows:

1 Chickens and other poultry are no longer "kept" in the hope that they will lay a few eggs or put on a little meat. The building materials of which eggs and meat are made are selected on the basis of costs, formulated in accordance with exact information, and fed into or onto the birds. As an ideal, this approach is not new. As a realization, it is new.

2 There are important relationships among nutrients, so it is not enough to say that the requirement of a nutrient is so many percent of the diet or so many milligrams per kilogram of diet. The relation of energy to protein is especially important because of the economic considerations emphasized by both Dr. Combs and Mr. Denton. When we call this a new concept, we have to acknowledge that the importance of the relation of energy to protein was recognized by European nutritionists before 1900. However, in poultry nutrition there was little opportunity to apply these ideas until the development of adequate information on requirements for other nutrients, notably vitamins and amino acids.

3 It is not enough to provide the essential amino acids at levels above the minima. They must also be in proper balance with each other and with energy. There is

increasing interest in the use of synthetic amino acids to achieve this balance.

4 It is possible, even in young chickens, to feed for maximal or minimal deposition of fat.

5 Because body composition varies so much, the number of pounds of feed required per pound of gain in broilers is a rather crude expression of efficiency. One may wish to supplement it with a statement of the percent retention of Calories or the number of feed dollars required for each product dollar.

6 Dr. Combs described a method for arriving at the "partial nutritional worth" of an ingredient on the basis of its content of required nutrients. Recently electronic computers have been used to work out least-cost rations to meet certain specifications.

7 Diets must be adapted to the birds for which they are intended. Diets for growing broilers differ from diets for growing flock replacement pullets. Diets for Leghorn breeders differ from diets for broiler-strain breeders. There is speculation that there may be differences in nutritional requirements even among strains that are grossly similar in body conformation and growth pattern.

8 Nutrient requirements change during the growth of pullets, and it is increasingly important, economically, to take account of these differences.

9 Although maximal feed intake is essential for broilers and probably for flocks producing market eggs, there are definite advantages in feed restriction for growing pullets and broiler-strain breeders.

10 Efficiency of conversion of feed to product is reduced not only by disease-producing microorganisms, but also by certain other microorganisms that do not cause recognizable disease. Antibiotics, arsenicals, and other drugs are very useful in counteracting the undesirable effects of such microorganisms. These drugs are supplements to good management, not substitutes.

11 Nutrient requirements are influenced by temperature and possibly by other variables in the physical environment.

12 Diets containing barley are improved by enzyme supplementation. The possibilities of enzyme supplementation in other types of diets are being studied extensively.

13 Certain estrogens can be used as dietary supplements to influence carcass composition.

14 It is possible to devise diets containing only known nutrients in pure or highly purified form, which will support growth and reproduction of chickens, through a complete life cycle. However, growth rate and reproduction rate are likely to be suboptimal unless such diets are supplemented with sources of unidentified nutrients.

Broiler Nutrition and Efficiency

By G. F. COMBS
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PERHAPS no animal industry has reflected progress in nutrition more vividly than has our rapidly expanding broiler industry. Its amazing progress in the last 25 years has been almost unbelievable. Actually, the first record of the number of broilers in the United States is available for 1934, at which time only 34 million broilers were produced. This supplied only 4.4 percent of the chicken meat consumed that year. In 1957, 78 percent of the total chicken meat consumed in this country was broiler meat, and undoubtedly the figure will be slightly higher for this year. In 1948, approximately 300 million broilers were produced, and since that time, the number has continuously rocketed to an estimated 1.8 billion broilers for 1959. This represents *a 53-fold increase* in the broiler industry during the last 25 years.

Along with improvements in breeding, management, disease control, and marketing technology, advances in broiler nutrition made possible this unequaled rate of industry expansion. Interestingly enough, the progress made in broiler nutrition and efficiency of production appears to have occurred in an accumulative manner during this period.

Only 5 years ago, I had occasion to write: "Before long, we should be able to produce 3 lb. broilers in 8 weeks with only 6 lbs. of feed. . . . Eventually, one should expect to produce a 3 lb. broiler with only 5 lbs. of total feed. . . ." Even now, the production of 3-pound broilers in 8 weeks with only 6 pounds of feed per bird under practical commercial conditions is not at all uncommon. And only last year, a feed efficiency of 0.96 (1.04 lbs.

TABLE 1
Progess in efficiency of broiler production, University of Maryland, 1952-58

	1952	*1955*	*1956*	*1955*[1]	*1958*[1]
Age, days ...	70	63	56	52	46
Wt., lbs ...	3.08	3.03	3.05	3.01	3.04
Feed/wt. ...	2.81	2.37	1.96	1.60	1.32
Energy intake per lb. (Calories)[2]					
Metabolizable ...	3,560	3,380	3,070	2,720	2,360
Productive ...	2,560	2,430	2,210	1,958	1,696
Percent of Calories retained in carcass[3]					
% of Metabolizable...	21.0	22.2	24.4	27.5	31.8
% of Productive ...	29.5	30.8	34.0	38.2	44.2

1. Males only; others include both sexes.
2. As calculated.
3. Assumed 750 Calories of gross energy/lb.

of feed per lb. of broiler) was obtained in the production of broilers to 3-pound body weights using special high potency rations (Combs, *et al.*, 1958).

Ration Formulation and Nutrient Levels

In formulating poultry rations one must know, first, the approximate requirement, or levels, of the various essential nutrients which should be provided by the ration. These are not too difficult to find, although the suggested levels of some are revised periodically, and it is not infrequent to find differences in opinion among nutritionists. Tables 2 and 3 present the levels of critical nutrients which the University of Maryland suggests for practical broiler rations. These levels are somewhat higher than the requirements indicated by the National Research Council for certain nutrients, but are presented as a guide in formulation of practical feeds.

Next, one needs composition data of the practical feedstuffs available for use and their prices. Formulation of a ration then becomes merely a matter of selecting those nutrients which are most favourably priced on the basis of their nutritional contribution and combining these in such proportions so that the

TABLE 2
Nutrient levels for practical broiler rations, University of Maryland[1]

Item		*Unit*	*Broiler starter (0-5 wks.)*[2]	*Broiler finisher (5-9 wks.)*
Energy:				
Productive	...	Calories per lb.[3]	950-1050	975-1075
Metabolizable	...	-do-	1420-1560	1360-1500
Crude protein	...	Percent[4]	21.6-25.0	18.7-22.0
Calorie/protein ratio:[5]	...			
Productive	...		42-44	49-52
Metabolizable	...		62-66	69-72
Calcium	...	Percent	1.0-1.2	0.9-1.1
Phosphorus:				
Total	...	-do-	0 70-0 80	0.65-0.75
Available[6]	...	-do-	0.45-0.55	0.4-0.5
Salt	...	-do-	0.3-0.4	0.3-0.4
Iodine	...	Mg. per lb.	0.5-0.6	0.5-0.6
Manganese	...	-do-	25-35	25-30
Iron	...	-do-	1.2-1.5	1.2-1.5
Zinc	...	-do-	20-25	20-25
Copper	...	-do-	0.15-0.2	0.15-0.2
Vitamin A	...	I.U. per lb.	3000	3000
Vitamin D	...	I.C.U. per lb.	300	300
Riboflavin	...	Mg. per lb.	2-3	2-3
Pantothenic acid	...	-do-	5-7	5-7
Niacin	...	-do-	18-28	18-28
Choline	...	-do-	650-900	
Cobalamin	...	Mcg. per lb.	3-5	2-4
Folacin	...	Mg. per lb.	0.3-0.4	0.3-0.4
Vitamin K[7]	...	-do-	0.36	0.36
Vitamin E[8]	...	I.U. per lb.	2.5-10	2.5-10

1. Requirements for nutrients not considered of critical importance in certain practical rations are not given. The lower levels are considered minimal for the lowest energy feeds. Nutrient levels should be increased above these proportionately, with energy.
2. Starters should be fed to approximately 2-lb. average weights.
3. Productive energy values of Fraps (1946), except for 2,900 Calories/lb. for fat. Metabolizable energy values are from Hill and Renner (1957).
4. Crude protein for a specific ration is determined by C/P ratio and energy levels.
5. Calorie-protein ratio varies with several factors including protein quality, growth rate, temperature, activity, feed intake, body composition desired, nutrient costs, etc.
6. Only one-third of the organically bound phosphorus considered available.
7. This amount in addition to that present in practical rations containing low levels of alfalfa meal.
8. Vitamin E requirement is greatly reduced by use of antioxidants.

TABLE 3

Estimated minimum amino acid requirements for broilers as related to energy content of the ration, University of Maryland

Productive energy	*Metabolizable energy*	*Estimated amino acid requirement*					
		Methionine	*Methionine & cystine*	*Arginine*	*Lysine*	*Trypto-phane*	*Glycine*
Chick and broiler starting rations: Calories per lb.		*percent of total ration*[1]					
900	1,350	0.43-.45	0.73-.80	1.03-1.20	0.90	0.20	1.00
950	1,420	.45-.47	.77-.84	1.09-1.26	.95	.21	1.06
1,000	1,490	.48-.50	.81-.88	1.14-1.32	.99	.22	1.11
1,050	1,560	.50-.52	.85-.92	1.20-1.38	1.04	.23	1.17
1,100	1,630	.52-.54	.89-.96	1.25-1.44	1.08	.24	1.22
Broiler finishing rations:[2]							
900	1,350	.37-.39	.61-.69	0.86-1.04	.81	.17	.87
950	1,420	.39-.41	.65-.73	0.91-1.09	.82	.18	.91
1,000	1,490	.41-.43	.68-.76	0.95-1.14	.86	.19	.96
1,050	1,560	.43-.45	.72-.80	1.00-1.19	.90	.20	1.01
1,100	1,630	.45-.47	.75-.83	1.04-1.24	.94	.21	1.05

1. Estimates for lysine, tryptophane, and glycine, and highest values for the others, were based on assumption that N.R.C. requirements are appropriate for chick starting rations containing 900 calories of productive energy/lb,
2. 86.5 per cent of the estimated requirements for starting rations.

nutritional requirements are met. Perhaps most important, careful calculation of rations is essential to make sure that the nutrient requirements are adequately met.

It is probably true that broiler rations are among the most difficult to formulate for most efficient and economical production. Nevertheless, if one is thorough in his approach and considers the levels of all critical nutrients in their formulation, good feeds should result. The critical factors in formulating the ration are the levels of available nutrients for the animal and not the amounts of specific feed ingredients which are supplied. No single feed ingredient is indispensable for good nutrition.

Of course many things are not quite as simple as they sound. For instance, there still appear to be unexplained growth responses which result from the inclusion of certain ingredients, particularly fish products; and until these nutrients are *identified, it appears desirable to add minimal quantities of these growth-promoting ingredients.* Other factors, such as the bulkiness and potency of a feed, must be considered and their effects on feed intake. Feeds which are high in energy content should also be formulated to be similarly high in their content of critical nutrients in order to maintain satisfactory nutrient balance in the ration. Of particular importance is maintaining an adequate balance in energy and protein (actually amino acids), since these items constitute the greatest portion of feed cost.

Selection of Economically Priced Ingredients

The most economical poultry ration should be the one which supplies all of the essential nutrients in adequate amounts for a given purpose at the lowest possible cost. To formulate economical rations, then, one must select feed ingredients for use based on their estimated relative nutritional worth. Accordingly, a method has been devised (Combs and Romoser, 1955 & 1959) which attempts to partially evaluate the nutritional worth of different feed ingredients. This evaluation is not complete since protein quality, unidentified factor activity, and other qualities of certain ingredients are not considered. The method is designed to determine the "partial nutritional worth" of each feed ingredient in terms of its estimated nutritive composition. The actual delivered prices of ground No. 2 yellow corn

and dehulled soybean oilmeal, 51 percent protein, are used as a base from which to determine the relative values of other feed ingredients, since corn and soybean oilmeal constitute the major sources of energy and protein in most poultry feeds.

Of the many nutrients which must be supplied in poultry feeds, fortunately, not all are of critical practical importance. In this calculation, the following price values have been used for the various critical nutrients, other than protein and energy, present in feed ingredients: Vitamin A activity, 12.5 cents per million units; riboflavin, 3.25 cents per gram; niacin, 0.72 cent per gram; pantothenic acid, 2.3 cents per gram; choline, 0.0906 cent per gram; vitamin B-12, 1.8 cents per milligram; calcium, 1.32 cents per pound; and phosphorus (available), 22.14 cents per pound. Only one-third of the phosphorus supplied by plant products is considered available.

By computing the market value of the amounts of these critical nutrients supplied by ground corn and soybean oilmeal, the value of a therm of productive energy and a pound of crude protein supplied by these two base ingredients can be calculated. Then the total value of the productive energy, crude protein, and critical vitamin and mineral content may be determined for each ingredient to determine its partial nutritional worth.

In order to simplify the procedure, equations are given in table 4 which have been derived for several commonly used poultry feed ingredients. The "partial nutritional worth" of each of these ingredients may be calculated in dollars per ton simply by substituting the proper values for X and Y (table 5) in the appropriate equation.

The values for X and Y are determined by the delivered prices of ground yellow corn and solvent soybean oilmeal. Therefore, it is necessary to use different values for X and Y as the price of one or both of these base ingredients changes.

Although the Partial Nutritional Worth calculation does not provide a complete answer in estimating the relative nutritional contributions of feed ingredients, it is a helpful start. For certain ingredients, a direct comparison of the partial nutritional worth with the actual marketing value gives very worthwhile information. For others, it is necessary to consider other important contributions of ingredients which have not been considered in this calculation. These include differences in

TABLE 4
Equations for calculating partial nutritional worth in dollars per ton of several feed ingredients[1]

Partial nutritional worth of		*Calculated value in dollars per ton*
Alfalfa meal, dehydrated 17%	=	3.4 X + 5.4 Y + 27.9
Alfalfa leaf meal, dehydrated 20%	=	4.0 X + 6.2 Y + 28.4
Barley, ground	=	2.4 X + 15.8 Y + 1.8
Blood meal	=	16.0 X + 20.0 Y + 1.84
Brewers dried yeast	=	9.0 X + 14.0 Y + 16.2
Buttermilk, dried	=	6.4 X + 14.0 Y + 7.4
Corn, yellow, ground	=	1.8 X + 22.8 Y + 1.4
Corn, gluten feed	=	4.4 X + 11.0 Y + 3.4
Corn, gluten meal	=	8.4 X + 16.4 Y + 4.5
Cottonseed meal, solvent	=	8.6 X + 12.4 Y + 4.7
Crab meal	=	6.2 X + 12.0 Y + 16.5
Distillers dried solubles (corn)	=	5.6 X + 16.0 Y + 8.1
Distillers dried solubles (molasses)	=	2.2 X + 12.0 Y + 3.7
Fats, stabilized	=	58.0 Y
Fish meal (menhaden), 60%	=	12.0 X + 17.6 Y + 23.0
Fish meal (sardine), 65%	=	13.0 X + 18.0 Y + 21.2
Fish solubles, condensed, 50% solids	=	6.0 X + 9.0 Y + 9.3
Hominy, yellow	=	2.2 X + 17.0 Y + 2.4
Liver meal	=	13.0 X + 21.0 Y + 22.1
Meat and bone scrap, 50%	=	10.0 X + 14.4 Y + 27.6
Meat scrap, 55%	=	11.0 X + 14.6 Y + 24.1
Milo, ground	=	2.2 X + 22.4 Y + 1.4
Molasses, cane	=	6 X + 14.0 Y + 2.0
Oatmeal, feeding	=	3.2 X + 23.0 Y + 2.1
Oats, pulverized	=	2.4 X + 15.2 Y + 1.6
Peanut meal	=	9.0 X + 17.0 Y + 4.6
Poultry byproducts meal	=	11.0 X + 17.6 Y + 11.2
Skim milk, dried	=	7.0 X + 10.5 Y + 7.4
Soybeans, ground, toasted, unextracted (10% moist)	=	7.5 X + 19.4 Y + 3.2
Soybean meal, solvent, 44%	=	9.2 X + 11.4 Y + 4.2
Soybean meal, dehulled, 50%	=	10.2 X + 12.8 Y + 4.4
Wheat bean	=	3.0 X + 9.5 Y + 4.2
Wheat, hard, ground	=	2.4 X + 20.4 Y + 2.0
Wheat midds, flour	=	3.2 X + 14.4 Y + 2.7
Wheat midds, shorts	=	3.4 X + 11.6 Y + 3.4
Whey, dried	=	2.4 X + 12.0 Y + 7.0

1. Solve each equation, referring to tables 2 and 3 for the calculated values of X and Y, respectively, based on the current market price of No. 2 ground yellow corn and soybean meal, dehulled, 51% protein, delivered at your location. The calculated partial nutritional worth values thus obtained are expressed on a delivered basis.

TABLE 5

Calculated value of crude protein and productive energy as influenced by the price of corn and soybean meal

Price of soybean oilmeal, dehulled, 51% protein (dollars per ton)	Price of ground yellow corn (dollars per ton)							
	40	*44*	*48*	*52*	*56*	*60*	*64*	*68*
	Value of crude protein (X) in cents per lb.							
50	2.61	2.37	2.13	1.88	1.64	1.39	1.15	0.90
54	3.04	2.80	2.56	2.31	2.07	1.81	1.58	1.33
58	3.47	3.23	2.99	2.74	2.50	2.24	2.01	1.76
62	3.90	3.66	3.42	3.17	2.93	2.66	2.43	2.19
66	4.32	4.08	3.84	3.59	3.37	3.09	2.86	2.62
70	4.76	4.52	4.28	4.02	3.80	3.52	3.29	3.05
74	5.20	4.96	4.72	4.46	4.24	3.95	3.72	3.48
78	5.63	5.39	5.15	4.89	4.68	4.39	4.16	3.91
82	6.07	5.83	5.59	5.33	5.11	4.82	4.59	4.34
86	6.51	6.27	6.03	5.77	5.55	5.26	5.03	4.78
90	6.94	6.70	6.46	6.20	5.98	5.69	5.46	5.22
94	7.38	7.14	6.90	6.64	6.42	6.14	5.90	5.65
	Value of productive energy (Y) in cents per therm							
50	1.48	1.68	1.88	2.06	2.26	2.46	2.65	2.85
54	1.45	1.65	1.85	2.03	2.23	2.43	2.63	2.83
58	1.41	1.61	1.81	1.99	2.19	2.39	2.59	2.78
62	1.38	1.58	1.78	1.96	2.16	2.36	2.56	2.75
66	1.35	1.55	1.75	1.93	2.13	2.33	2.53	2.72
70	1.31	1.51	1.71	1.89	2.09	2.29	2.49	2.68
74	1.28	1.48	1.68	1.86	2.06	2.26	2.46	2.65
78	1.25	1.45	1.65	1.83	2.03	2.23	2.43	2.62
82	1.21	1.41	1.61	1.79	1.99	2.19	2.39	2.58
86	1.18	1.38	1.58	1.76	1.96	2.16	2.36	2.55
90	1.14	1.34	1.54	1.72	1.92	2.12	2.32	2.51
94	1.11	1.31	1.51	1.69	1.89	2.09	2.29	2.48

protein quality, unidentified factor activity, differences in bulk densities, toxic substances, palatibility effects, etc.

High Energy (High Potency) Broiler Rations

Of the many recent advances in formulation of broiler rations, perhaps the use of "high energy" or "high efficiency" or "high potency" rations deserves special mention. This embodies several contributing factors, including the use of

added stabilized fats, the use of less high-fiber low-energy feedstuffs, consideration of physical form, potency and feed intake and the use of the Calorie/protein ratio[1] as a guide in determining the protein levels required for feeds of widely different energy content. These are somewhat interdependent, but an attempt will be made to discuss them separately.

High Corn Levels and Added Fat

Shorly after the discovery that high corn diets required additional niacin fortification to the low tryptophane content, Scott *et al.* (1947) at Connecticut developed the first high energy broiler ration. This involved the use of a high level of corn and minimized the use of high-fiber low-energy ingredients. This ration was considerably more efficient than feeds had been, but feather picking resulted and it became necessary to debeak broilers. In retrospect, this ration appeared to contain more energy than its protein or amino acid levels could properly support.

At that time, investigators had reported that 8 percent fat was all that the chicken could tolerate and high levels caused loss of feathers and poor growth. The discovery in 1950 that antioxidants could be added to fats or to feeds containing fat, thus preventing rancidity and concurrent destruction of certain nutrients, studies were again initiated to determine the levels of added stabilized fats which might be satisfactorily used. Obviously, the addition of fats and the removal of high-fiber, low-energy ingredients resulted in a considerable increase in the energy content of the ration on a weight or volume basis. It suddenly became apparent that considerable attention must be given to a re-examination of the protein or amino acid requirements in relation to the energy potency of the feed.

Energy-Protein Balance

Combs and Romoser (1955) were able to produce broilers averaging 3 pounds in 7½ weeks on 1.60 lbs. of feed per pound of body weight. This was done with a ration containing 15 percent added stabilized animal grease with consideration given to the

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1 Calories of productive energy per pound divided by the percentage of protein in the feed. "Calorie" as used in this sense=1 large calorie of 1,000 small calories.

need for additional nutrients, particularly protein, as the energy concentration of the feed was increased. The term Calorie/protein ratio was introduced for the purpose of guiding nutritionists in the formulation of practical poultry rations. It was estimated that a C/P ratio of 42 Calories of productive energy per pound gave the most economical results for broiler starting rations.

In a series of studies involving carcass analysis, it was found that the fat content of the 4-week-old chick could be increased 1.8 fold before any difference in rate of gain was observed. This was accomplished as the C/P ratio was widened (as the amount of protein was lowered in relation of energy). In addition to increased energy intake and increased body fat deposition, feather picking was observed and eventually growth rate was reduced as the ratio of energy to protein was widened further. The energy uptake per pound of broiler increases and the protein uptake per pound of broiler decreases as the C/P ratio is widened. Based on results of several trials and different prices for corn and soybean meal, the most economical C/P ratio appeared to range from 41-43:1 for broiler starting feeds. Other studies indicated that a ratio of approximately 49-52:1 is satisfactory for broiler finishing rations.

Obviously, many factors can be expected to influence the most economical C/P ratio for use in broiler feeds, since any factor which would influence the protein requirement in relation to energy requirement would be expected to influence the ratio between the two. Among those factors are protein quality, rate of growth, activity, environmental temperature, degree of fatness desired, relative cost of energy and protein nutritional composition data and differences in feed intake.

Though this is not a new concept, it has been very satisfactorily applied in the estimation of protein levels for practical rations differing widely in energy content. With this approach, it is now possible to use any level of added fat (up to 50 percent has been used) with excellent results. It was with such a diet that a feed conversion of 1.04 was obtained for 3-pound broilers at the University of Maryland.

Added Fat in Practical Rations

Although there appears to be no nutritional limit as to the level of fat which may be used, the level used in most practical

rations is determined largely by economics. The average broiler feed contains approximately 2 percent added fat although some contain more. The addition of higher fat levels to dry mash feeds increases their palatability, potency, efficiency and in certain rations provides a means of improving the quality of the total protein.

A summary of several studies conducted at Maryland reveals that the addition of stabilized fats to broiler feeds reduced the feed intake in a matter which was predictable, based on the calculated increase in energy content of the feed, when the rations were formulated to maintain satisfactory nutrient-energy balance. Growth responses have consistently been obtained in practical tests where 10 percent fat was added to dry mashes. Pelleting, however, also improves growth to a similar extent and the pelleting of feeds containing 10 percent added fat has exerted no further benefit. Similarly, the inclusion of 10 percent fat in pelleted rations does not improve the growth rate. This illustrates the importance of feed potency as a function of nutrient intake and subsequent rate of growth in broiler production.

Protein Quality and C/P Ratio

Of course, the amino acid makeup of the protein is extremely important in the use of C/P ratio since the role of protein is to supply the necessary amounts of amino acids. Studies have been done recently with corn-soybean meal type rations where the protein levels may be reduced by approximately 10 percent when methionine is added to supply adequate amounts of this amino acid. In several studies, C/P ratios of 48:1 in broiler starter feeds and 55:1 in broiler finisher feeds have proved as satisfactory as narrower ratios, provided that these rations containing the lower protein levels supplied adequate amounts of all the essential amino acids in relation to the energy content of the feed.

This improvement in efficiency of protein utilization illustrates well the critical importance of amino acid makeup of our practical rations. Fortunately, a mixture of corn and soybean meal protein is relatively high in lysine and tryptophane with only the sulfur amino acids being suboptimal. Some work indicated that glycine might also be suboptimal on such diets,

although our own research has not indicated and confirmed this observation with low-protein simplified pratical rations.

In studying protein or amino acid requirements, it appears important to measure changes in body composition as well as rate of growth in order to more adequately interpret the results.

Other Nutrients

The nutritionist is still faced with the problem of supplying "unidentified growth factors" in the broiler ration, although much of the recent work conducted at the practical level shows comparatively little improvement. In our own studies, we have been unable to obtain responses from "whey factor" supplements in either turkey or broiler feeds, but do obtain a very slight improvement when "fish factor" supplements are added. This amounts to about 2-2 ½ percent heavier birds at 8 weeks with an average of ½-1 percent less feed per unit of gain on the average. Though these differences are not great, they do indicate the existence of some unrecognized effect associated with the use of these materials.

Part of the growth responses which have been attributed in the past to "unidentified factors" undoubtedly were due to insufficient available zinc, amino acid inadequacy, differences in feed intake resulting from changes in palatability and potency, and other factors. Zinc supplementation has consistently improved growth rate of turkeys in our laboratory, and other research groups have obtained responses with broilers fed similar simplified corn-soybean meal rations.

Another observation of practical significance in broiler nutrition is the relationship between choline and methionine requirements. Maryland data indicates that rations containing 10 percent added fat require approximately 900 milligrams of choline per pound in order to minimize the need for supplemental methionine. Such a ration appears to have a higher requirement for methyl groups, which can be supplied by either choline or methionine.

Certainly, a most important factor in the development of efficient broiler feeds has been the use of antibiotics, arsenicals, and cocciodiostats. Antibiotics are used widely at nutritional levels (from 2 to 10 grams per ton) as well as for

disease prevention and control. Recent work has shown that the effect of certain antibiotics can be materially enhanced by lowering the calcium levels. Arsenicals are generally used for growth promoting purposes, and cocciodiostats are essential for control of coccidiosis. In spite of the use of these drugs routinely, emphasis is still placed on the need for good management and sanitation for most efficient broiler production. Though these drugs are extremely helpful, they cannot completely replace the need for good sanitation and management.

TABLE 6
Yardstick for determining broiler feed values[1]

C/P ratio		*Productive energy*						
Starter	*Finisher*	*880*	*920*	*960*	*1000*	*1040*	*1080*	*1120*
					Calories per lb.			
42	48	2.50	2.39	2.29	2.20	2.12	2.02	1.96
44	50	2.56	2.45	2.34	2.25	2.17	2.07	2.01
46	52	2.62	2.51	2.40	2.30	2.22	2.12	2.06
48	55	2.68	2.57	2.46	2.36	2.27	2.17	2.11
50	58	2.75	2.63	2.52	2.42	2.33	2.22	2.16

1. These values represent the estimated amount of feed required to produce a pound of broiler, when 3-pound weights (both sexes) are reached in 8 weeks, as influenced by the energy content and Calorie/protein ratio of the feed. These values are based in part on data from field trials conducted at the University of Maryland.

TABLE 7

[Example] Simplified broiler rations, University of Maryland trials S-25, 26

Ingredients	*Starting rations*			*Finishing rations*		
	S-1	*S-2*	*S-3*	*F-1*	*F-2*	*F-3*
			lb.			
Ground yellow corn	1,276.75	1,134.5	1,075	1,366	1,233.6	1,181
Stabilized fat	40	120	120	40	120	120
Fishmeal, menhaden, 60%	50	50	50	40	40	40
Meat and bone scrap, 50%	—	—	75	—	—	60
Poultry byproducts meal	75	75	75	60	60	60
Soybean meal, 50%	420	480	450	315	365	340
Corn gluten meal	50	50	50	75	75	75
Dehydrated alfalfa meal, 20% (150,000 I U of A/lb.)	25	25	25	40	40	40
Dried whey product (50% lactose)	—	—	40	—	—	40
Limestone	20	20	12	20	20	12
Dicalcium phosphate	28	28	12	28	28	15
Salt	6	6	6	6	6	6
Trace mineral mix[1]	2	2	2	2	2	2
Choline chloride, 25% mix	—	2	1	1	3	2
DL-methionine	.25	0.5	—	—	0.4	—
Special mix[2]	7	7	7	7	7	7
Total	2,000	2,000	2,000	2,000	2,000	2,000
Calculated/analysis:			*Calories per lb.*			
Productive energy	997	1,052	1,048	1,026	1,074	1,071
			Percent			
Crude protein	20.7	22.0	23.4	18.7	19.4	20.6
C/P ratio	48:1	48:1	45:1	55:1	55:1	52:1

1. Supplies 60 ppm manganese, 1.2 ppm iodine, 2 ppm copper, 0.4 ppm cobalt, 25 ppm iron, and 18 ppm zinc in final feed.
2. Supplied per ton: BHT (Butylated hydroxytoulene [100%]), 0.25 lb.; choline chloride (100%), 1 lb.; menadione sodium bisulfite,

1 gm.; riboflavin, 4 gms.; niacin, 30 gms.; D-calcium pantothenate, 10 gms.; procaine penicillin, 4 gms ; sodium molybdate, 1 gm.; alphatocopherol acetate, 1,000 I.U.; DL-methionine, 0.75 lb.; vitamin B-12, 6 mg.; vitamin A, 3 million I.U.; vitamin D-3, 0.8 million I.C.U.; 3-nitro, 4-hydroxy phenyl arsonic acid, 45 gms.; and a cocciodiostat.

REFERENCES

Combs, G. F., E. C. Quillin, N. V. Helbacka, C. D. Caskey, 1958. Studies on High Efficiency Broiler Rations. Misc. Pub. No. 323, Md. Agr. Exptl. Sta.

Combs, G. F. and G. L. Romoser, 1955. A New Approach to Poultry Feed Formulation. Misc. Pub. No. 226, Md. Agr. Exptl. Sta.

Combs, G. F. and G. L. Romoser (revised 1959). Method for Calculating the "Partial Nutritional Worth" of Feed Ingredients for Poultry Rations. Misc. Pub. No. 158, U. of Md. Ex. Service.

Hill, F. W. and Ruth Renner, 1957. Metabolizable Energy Values of Feedstuffs for Poultry and Their Use in Formulation of Rations. Proc. Cornell 1957 Nutr. Conf. for Feed Manufacturers, Page 22.

Scott. H. M., L. D. Matterson and E. P. Singsen. Poultry Science 26: 554. 1947.

Laying Hen Nutrition

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DURING the last 25 years, the poultry industry in this country has matured. It is now well over a $3-billion-a-year business. The increase in laying hens has not been nearly so great as the increase in broilers and the efficiency of feed conversion of the layer has not improved to the dramatic extent experienced in broiler production.

In the early 1930's, the annual production was about 34,429 million eggs, and in 1958 slightly more than 61,000 million eggs—an increase of about 77 percent. During this interval, the countrywide average yearly production per hen increased from 120 to 201 eggs.

In 1930, approximately 7.8 pounds of feed were required to produce a dozen eggs. At the present, the average for the country is around 6.5 pounds. This is not a striking improvement. However, in many of the better commercial flocks this figure may be as low as 5.3 pounds per dozen, and under laboratory conditions with high-producing strains, a dozen eggs may be produced with less than 4 pounds of feed.

It should also be pointed out that during the last 15 years, the average body weight of the light breed layers has dropped from 5.5 to 4.4 pounds. This offers a definite advantage in feed conversion because there is less body weight to maintain.

Breeding has been important in improving rate of lay, for if a hen does not have the genetic capacity for high

production, the best diet formulated will not make her a 250-egg bird. On the other hand, the inherently high producer will be a poor performer on an inadequate diet.

Thus, in the continuing struggle for more efficient performance of layers, breeding and nutrition are basic considerations. The question is asked quite frequently. Has the genetic ceiling been reached? Judging by the results of various laying tests, this appears to be the case. Although the national average is still considerably lower than the laying tests averages, it continues to increase and there is no indication of its leveling off. However, it will do so inevitably, and when this occurs, nutrition will have a greater responsibility in the effort to produce a dozen eggs for the least possible cost.

In order to obtain an optimum degree of success in this effort, the diet must be tailored to the type of bird being fed, *i.e.*, replacement pullets, light-breed commercial layers, and broiler-strain breeding stock. The formulation of that diet depends on a host of factors which each poultryman and feed manufacturer must evaluate for his own specific conditions.

Based on accepted formulation at current prices of feedstuffs, it has been calculated that carbohydrate accounts for about 52 percent of the cost of a diet, and protein about 41 percent, leaving vitamins, minerals, and other ingredients to make up the remaining 7 percent. It is obvious that in the economics of formulation, carbohydrates and proteins are major considerations. The other ingredients are extremely important, not because of their cost, but because of their effect on the proper utilization of carbohydrates and protein.

Let us consider some of the ingredients which make up the 7 percent cost of diet in respect to their requirement by laying and breeding hens, and some of the more recent experimental work concerning these requirements. The requirements of laying hens, about which there is reasonable factual information, are outlined by the National Research Council.([1]) The essential difference between laying and breeding hens is that the latter require more riboflavin, pantothenic acid, and folic acid. The breeding hen also

requires vitamin B^{12} for good hatchability and livability of the progeny. The tentative requirement is indicated as 2 micrograms per pound of feed. The manganese requirement of the layer is not known but 15 milligrams per pound is indicated for the breeder. Also, the iodine content of breeder's diets should be about twice that of laying diets.

Since many factors, such as breed difference, environment, energy content of the diet, and interaction of various nutrients, may affect dietary requirements, the values given in the National Research Council publication are continually being revised. Heywang(2) at our experiment station in Glendale, Arizona, found that 2,500 units of vitamin A per pound of feed were sufficient for egg production when temperatures were moderate, but in extremely hot weather the requirement was 3,700 units per pound. The high temperature did not affect the requirements of vitamin A as such, but acted indirectly by depressing feed consumption. This finding demonstrated that the margins of safety necessary in addition to basic nutrient requirements may vary with both location and season.

Workers at the Storrs experimental station(3), using diets low in vitamin E, have shown that egg production is not affected by vitamin E nutrition. Hatchability and fertility were lowered by vitamin E deficiency. Workers at Oklahoma State University(4) have indicated that levels of niacin, pantothenic acid, and folic acid higher than those recommended by the National Research Council are needed in high-energy laying rations for maximum egg production and economy of feed conversion. These and other experiments point to the necessity of adequate supplies of nutrients in breeder diets to insure good performance of the progeny.

On the other hand, oversupply of vitamins in the laying diets may have an adverse effect. Recently, the Washington State College group(5) added vitamins of the B complex in considerable excess of the National Research Council recommendations to both high and low energy diets. The excess of vitamins resulted in a decrease in egg production. Also, investigations at the University of Idaho(6) have demonstrated that excess vitamin supplementation lowered feed conversion.

A glaring weakness in poultry nutrition research is lack

of work on mineral requirements. Calcium phosphorus, manganese, and salt have been routinely considered in feed formulations in accord with the recommendations of the National Research Council, but trace minerals have been almost entirely neglected. In some of the few recent reports, O'Rourke, *et al.*(7) have reported that 0.3 percent phosphorus in the diet appears adequate for hatchability.

In studies on the phosphorus requirements for layers, Gillis and coworkers(8) have found that phytin phosphorus was relatively poorly utilized in comparison to inorganic phosphorus supplied by dicalcium phosphate and deflourinated phosphate. Although the hen appears to be able to use more of the phosphorus from phytin than the chick, only 50 percent of the phytin phosphorus is available in comparison to the phosphorus of inorganic supplements.

Although it has been shown that sources of unidentified growth factors, such as fish solubles, liver, alfalfa meal, and grass juice, are necessary for normal reproduction on simplified and purified diets, their exact role in practical breeder diets can not be evaluated at the present time. However, most commercial breeder rations do contain some sources of these factors for insurance of optimum nutrition.

Energy and Protein

The economics of egg production necessarily starts with the growing of replacement flocks. Research in this phase of production is being centered around nutritive requirements, particularly protein, and restricted feeding.

Research at Wisconsin(9) has indicated that on a diet containing 800 calories of productive energy per pound the protein level should be at least 20-21 percent for the first 6 weeks, but that after 6 weeks, 15-percent protein permitted normal weight gains. With a diet containing 960 calories, 15-percent protein from hatching to maturity did not give optimum weight gains; however, all differences had disappeared by the time the pullets were 28 weeks of age. From the 10th to the 20th week, 13 to 14-percent protein gave maximum growth rate. As the percent protein was reduced feed cost tended to be lowered.

Results at Beltsville show the same general trend. The

experimental design using White Leghorn chickens was as follows: 21-percent protein to 8 weeks and then 16 percent to maturity; 16 percent from hatching time to maturity; 16 percent to 8 weeks and then 12 percent to maturity; 12 percent from hatching to maturity. The only difference in weight noted at 26 weeks of age was that the pullets on 12-percent protein from hatching to maturity were about 0.2 of a pound lighter than those on 21-percent protein to 12 weeks and then 16 percent to maturity. The various protein levels in the growing diets had no effect on subsequent henhouse performance. This is in agreement with the results obtained at Wisconsin.

During the last several years the practice of restricted feeding of replacement pullets from 8—10 weeks to maturity has received considerable attention. Three ways that this may be accomplished are (1) restricting the total quantity of feed intake, (2) diluting the feed with a fibrous material of low nutritive value, and (3) limiting the time the feed is before the birds.

We have used the first two methods at Beltsville. The first resulted in substantial savings in feed cost, whereas the second method gave no savings. In this trial the birds simply ate more feed. However, it has been our experience that the system can be evaluated best on the basis of subsequent performance. In all cases, egg production of the restricted birds was somewhat higher than that of the nonrestricted groups and mortality was considerably lower. Our results, together with those of other laboratories, certainly indicate that some form of feed restriction is desirable during the growing period. In this type of feeding program care must be taken to avoid vitamin and mineral deficiencies.

Protein and energy in laying diets have been extensively investigated during the last several years. The protein level in laying diets recommended by the National Research Council is 15 percent. The question has been raised as to whether this quantity of protein is adequate with high producing strains of hens and high energy diets. There have been at least eight reports that protein levels lower than 15 percent will give optimum production and three or four reports indicating that levels above 15 percent are necessary.

Three different studies at Beltsville have indicated that a 12-percent protein level is adequate in laying diets but in a more recent study 16-percent protein has given better results than 12 percent. These divergent results clearly indicate that many factors influence the efficiency of protein utilization and apparent requirement. Judging from the literature reports, breed does not appear to have a consistent effect on protein requirement, but the possibility of strain difference must not be overlooked. Among the factors that may influence apparent requirement are balance of amino acids in the protein, inter-relationship between protein (amino acids) and other dietary constituents, level of production, variation in the utilization of nutrients, and age of the bird.

However, the basic problem in this phase of hen nutrition is not what protein source to use or what dietary level to employ, but what quantity of essential amino acids a hen needs. Information on this is incomplete since the hen's requirement for only three of the essential amino acids (lysine, methionine, and tryptophane) is known with a reasonable degree of accuracy.

Perhaps the most spectacular development in poultry nutrition in recent years is concerned with the energy requirements of poultry and relationship of energy content of the diet to protein requirement. The Connecticut Broiler Ration was formulated in 1947 demonstrating the effectiveness of high-energy diets. However, the development of this phase of poultry nutrition did not gain full momentum until 4 or 5 years ago when the United States had immense supplies of inedible fats and means were sought to utilize them. The studies of various investigators had previously substantiated the concept that diets low in fiber and high in energy were more effective for egg production than those high in fiber and low in energy. Thus, the availability of surplus fat at prices which made it economically feasible to feed offered an excellent method for increasing dietary energy. Lillie and coworkers([10]) at Beltsville were, I believe, the first to show that the addition of lard to a laying diet gave a substantial improvement in feed conversion. Subsequent work in many laboratories has rather consistently shown that increases in dietary energy have

little or no effort on egg production but give an improved feed conversion. However, in some feeding trials, the addition of fat did not result in the improvement expected for the increased energy content of the diet thus deviating from the linear relationship established by Hill[11]. In contrast, the Rutgers workers[12] have reported no improvement in feed conversion from feeding 10 percent corn oil or tallow. Also, the Rhode Island group[13] did not obtain consistent improvement when animal fat was added to the laying diet and they also encountered increased mortality with the addition of fat.

The results of recent studies at Beltsville are somewhat comparable with those of the latter investigators in respect to feed conversion. Feeding tests with broiler-type New Hampshire and White Leghorn pullets on two energy levels resulted in a decided improvement on the high-energy diet, whereas Rhode Island Red pullets showed practically no improvement of feed conversion on high energy.

In general it appears that maintaining a definite ratio between dietary energy and protein content is not as important in laying diets as it is in growing diets. Studies (Beltsville and Wisconsin) demonstrated that laying hens can tolerate a wide calorie-protein ratio without any impairment in performance. However, from an economic standpoint, there is probably an optimum ratio.

The nutrition of the broiler strain of breeder hen presents a problem different from that of commercial laying flocks. It has been generally accepted that controlled feeding of laying hens results in poor performance. However, poultry producers are confronted with a special problem in feeding broiler-type breeding hens. The characteristics of good broiler stock, such as rapid growth and ability to convert feed efficiently into body tissue, are a disadvantage in the adult breeding bird. The capacity to eat, together with comparatively low egg production, causes excessive body weight and decreases efficiency of feed utilization. In order to avoid attendant obesity and the resulting poor performance, various types of diet formulation, varying protein and energy, and restricted feeding practices have been investigated. Feeding a low-energy ration is one way to control energy intake, but this procedure results in an increased feed intake which in turn usually results in a high

feed cost per dozen of eggs. In general, it seems that the best feed conversion may be obtained with a controlled intake of a high energy diet.

Antibiotics

The results of studies on the effects of antibiotics on laying hen performance have been more controversial than those with growing chicks. Some work at Beltsville has furnished the possible explanation for these contradictory reports. Our findings indicate that when a hen is laying below her genetic capacity because of stress conditions or subclinical infection, antibiotics may improve production. On the other hand, when a healthy bird is producing at or near her genetic capacity, antibiotics feed is of little value.

Studies at our Glendale station(14) have shown that high-level antibiotic feeding (50 to 100 grams of clortetracycline per ton of feed) consistently improved egg production during the extremely hot summer months encountered in that area.

LITERATURE CITED

(1) Nutrient Requirements for Poultry, Publication 301, 1954. National Research Council.

(2) Heywang, B. W., The level of vitamin A in the diet of laying and breeding hens during hot weather. 1952. Poultry Sci. 31: 294—301.

(3) Singsen, E. P., L. D. Matterson, A. Kozeff, R. H. Bunnell and E. L. Jungherr. 1954. Studies on encephalomalacia in the chick. 1. Influence of vitamin E deficiency on the performance of breeding hens and their chicks. Poultry Sci. 33: 192—201. 1954.

(4) Thayer, R. H., 1953. Vitamin Levels in high energy layer-breeder rations. Poultry Sci. 32: 927.

(5) Berg, L. R. and G. E. Bearse. 1956. The effect of water-soluble vitamins and energy level of the diet on the performance of laying pullets. Poultry Sci. 35: 945—951.

(6) Anderson, G. J., C. F. Petersen, A. C. Wiese and C. E. Lampman, 1957. The effect of high level vitamin supplementation of high and low energy rations on egg production and egg shell quality. Poultry Sci. 36: 1369—1375.

(7) O'Rourke, W. F., H. R. Bird, P. H. Phillips and W. W. Cravens. 1954. The effect of low phosphorus rations on egg production and hatchability. Poultry Sci. 33: 1117—1122.

(8) Gillis, M. B., L. C. Norris and G. H. Heuser, 1953. Phosphorus metabolism and requirements of hens. Poultry Sci. 32: 977—984.

(9) Sunde, M. L. and H. R. Bird, 1959. The protein requirements of growing pullets. Poultry Sci. 38: 48—55.

(10) Lillie, R. J., J. R. Sizemore, J. L. Milligan and H. R. Bird. 1952. Thyroprotein and fat in laying diets. Poultry Sci. 31: 1037—1042.
(11) Hill, F. W. 1956. Studies of the energy requirements of chickens. 4. Evidence for a linear relationship between dietary productive energy and efficiency of egg production. Poultry Sci. 35: 59—63.
(12) Leveille, G. A. and H. Fisher, 1958. Observation on lipid utilization in hens fed vegetable and animal fat supplemented diets. Poultry Sci. 37: 658—664.
(13) Donaldson, W. E. and R. I. Millar. 1958. Observations on added fat in laying rations. Poultry Sci. 37: 1199.
(14) Heywang, B. H. 1957. The relative effect of two high levels of an antibiotic on laying chickens during hot weather. Poultry Sci. 36: 871—873.

Improved Feed Ingredient Processing

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IT is generally expected that a compounded feed, in terms of its potential performance, will be no better in quality—even if skillfully formulated and adequately mixed—than the quality of the separate ingredients used in its manufacture. It is quite possible, by the use of published tables of analytical data, to predict with some degree of accuracy likely deviations in feeding quality of many ingredients, such as most of the grains, grain by-products, and roughages. By having available for each representative sample such information as unit weight (weight per bushel is commonly used for grains in the United States), percent of damaged material, percent of foreign matter, content of fiber, protein and moisture, additional accuracy is possible in predicting the potential value of a feed mixture. Since grains, as well as several other ingredients, can go out of condition during storage, the practice prevails in many markets of appropriately labeling or identifying damaged commodities when offered for sale. The following are familiar qualifying labels—bin damaged, field damaged, fire damaged, and water damaged.

Undoubtedly, one of our most variable ingredients, in terms of potential performance in feeds, comes under the heading of "protein sources." These products can vary considerably depending on the source or quality of the raw material used in producing them. However, one of the most common causes of quality variance is heat—either too much or too little.

Heat applied to feed or food materials may have good or

bad effects. If applied properly, heat removes moisture safely, thus reducing the risk of spoilage by fermentation or enzymatic action and the like during storage. Use of the proper amount of heat during processing is known to be highly beneficial to the biological value of the proteins of soybean products, such as soybean oilmeal. A few other legumes, such as navy beans, are similarly affected but soybean oilmeal interests us most because of its availability here in the United States and its worldwide importance as a potential source of good protein.

Excess heat during processing can be detrimental to all of our commonly used protein meals, such as fish meal, meat meal, dried milk products, cottonseed meal, sesame meal, and even soybean oilmeal. The questionable feature about this effect of heat—either good or bad—on these protein meals is that in most cases there is no satisfactory method available for quickly detecting protein improvement or damage in the case of soybean oilmeal, or for detecting protein damage as in fish meal and many other proteins. The only sure way of determining the biological value of these proteins is to subject each meal to a protein bio-assay. We have never heard of a supplier publicly announcing an overheated protein ingredient for sale, unlike marketers of grains and grain byproducts, nor have we ever heard of a soybean processor labeling his meal as underheated for good protein nutrition of young poultry and pigs. Yet over the years a considerable tonnage of protein has been sold that was distinctly inferior because of improper heat treatment during processing.

Back in the 1920's and early 1930's several investigators working independently found that when certain food materials, such as casein, cereals, and fish meals, were exposed to high temperatures, they decidedly decreased in nutritive value of the protein. Flame-dried fish meals (temperature 400°—600° F. for 30 minutes) were always found to have a lower biological value than the low temperature steam and vacuum dried meals. Most decreases in the protein efficiency of fish meal caused by over-heating were thought to be due to damage to the amino acids—lysine, arginine and cystine. This work was done before the role and importance of methionine was generally recognized. That is why methionine was not

mentioned in this early work ([8]) as one of the limiting amino acids due to overheating. In protein damage resulting from the overheating of milk products and cereals, the amino acids—lysine and histidine—were usually affected.

TABLE 1

Amino acid content of various feed ingredients

Ingredient	*Protein*[1]	*Lysine*	*Tryptophan*	*Cystine*	*Methionine*
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Corn	9.0	0.3	0.10	0.16	0.18
Soybean oilmeal	45.0	3.2	.58	.66	.67
Cottonseed meal	43.0	1.8	.52	.86	.65
Linseed oilmeal	35.0	1.2	.56	.66	.60
Peanut meal	44.0	1.4	.48	.70	.44
Corn gluten meal	42.0	.7	.21	.76	.84
Meat scraps	50.0	3.1	.35	.60	.65
Fish meal	60.0	5.7	.84	.90	1.62
Skim milk (dried)	35.0	2.5	.45	.42	1.05

1. Nitrogen x 6.25.
Source: Richard J. Block, *"Amino Acid Handbook—Methods and Results of Protein Analysis,"* pp 296-297, Chas. C. Thomas, Springfield, Ill.

Table 1 gives the content of a few of the important amino acids found in various feed ingredients. Even though corn is only one grain protein—corn—is listed, this table serves to illustrate the fact that grain proteins, and grain or cereal byproducts as a whole, are extremely low in lysine content. The protein of corn is also limited in tryptophan content and is rather low in cystine and methionine. The various oilseed meals vary considerably in lysine, with properly cooked soybean oilmeal at the head of the list of plant-type proteins in lysine content. Fish meal and meat meal can be good sources of lysine. Fish meal is usually the best of these animal-type proteins in tryptophan, cystine, and methionine—at least better than most meat meals currently available on the market. However, it is well to keep in mind that lysine is ordinarily one of the amino acids most vulnerable to damage by overheating. Methionine and cystine are usually next in order. It is evident that we do need proteins rich in lysine to balance the proteins of grain in critical rations. If

appropriate raw materials are used in producing animal-type protein meals, including fish meals, they will usually show a good content of available lysine, provided the meals are not heat damaged during processing. (References [1] and [12].)

Soybean Oilmeal

Effect of Heat.—Soybean oilmeal contains an excellent protein as to quantity and to kind and amount of essential amino acids, provided it is properly cooked during processing. The soya products listed in table 2 represent a series made at the same time in one processing plant (continuous solvent extraction) with the treatment purposely varied from raw or as is (in raw soybeans) through different degrees of heating or cooking until an excess was reached, labeled as "overheated." Soybean Sample 4, identified as Properly Cooked, contained moisture in excess of 18 percent in flake form after defatting and before, as well as during, cooking. All the cooking of these soya products (Samples 3, 4, and 5) was done in atmospheric cookers that were steam jacketed. Both live steam and

TABLE 2
Effect of cooking on protein efficiency of soya products

Soya Sample number	*Identity of products*	*Protein source*	*Relative protein efficiency (Milk=100)*	*Criteria*	
				Water dispersible protein	*Urease increase in pH*
			Percent	*Percent*	
	Control	Skim milk	100		
1	Soybeans (raw)	Soya	30	76.4	1.90
2	Soybean oilmeal (unheated).	Soya	36	76.2	1.80
3	Soybean oilmeal (mildly heated).	Soya	70	41.6	.75
4	Soybean oilmeal (properly cooked).	Soya	89	14.2	.20
5	Soybean oilmeal (over-heated).	Soya	81	5.1	.05

Note: These rat assay results summarize a 56-day test using 5 male albino rats of the Sprague-Dawley strain per lot. The protein in all of the diets was equalized at a 10-percent level. The diets used were a purified type with all the protein supplied by the products indicated in the column titled "Protein source."

atomized moisture were injected inside of the cookers. The best meal, Sample 4, was cooked for some 60 minutes at a temperature not over 220°F.

The raw soybeans and improperly cooked soybean oilmeal had a low relative protein efficiency. Overheating reduced the protein efficiency as compared to that of the optimum cooked meal (sample 4). The changes shown in water-dispersible protein and urease activity are fairly typical values for soybean oilmeals cooked in atmospheric cookers. We find a

TABLE 3
Amino acid studies with raw and cooked soybean oilmeal

Lot No.	*Protein source*	*Relative protein efficiency milk=100*
		Percent
1.	Dried skim milk control	100.0
2.	Raw soybean oilmeal (defatted, unheated)	78.3
3.	Raw soybean oilmeal + choline[1]	81.3
4.	Raw soybean oilmeal + 1 percent L lysine	80.1
5.	Raw soybean oilmeal + 0.3 percent DL methionine	102.4
6.	Raw soybean oilmeal + essential amino acids[2]—methionine	71.3
7.	Raw soybean oilmeal + essential amino acids including methionine	91.6
8.	Cooked soybean oilmeal[3]	102.4
9.	Cooked soybean oilmeal + choline	103.0
10.	Cooked soybean oilmeal + 1 percent L lysine	99.4
11.	Cooked soybean oilmeal + 0.3 percent DL methionine	103.0
12.	Cooked soybean oilmeal + essential amino acids—methionine	94.0
13.	Cooked soybean oilmeal + essential amino acids including methionine	98.2
14.	44 percent soybean oilmeal commercial production	103.6

1. Choline chloride to supply 200 mg. choline per 100 gm. diet.
2. The amino acids used with levels indicated are as follows: L lysine .5 percent, DL methionine .3 percent, DL tryptophane .1 percent, DL histidine .2 percent, DL phenylalanine .3 percent, DL leucine .4 percent, DL isoleucine .2 percent, DL threonine .3 percent, DL valine .3 percent, L arginine .1 percent.
3. Prepared from the raw soybean oilmeal by autoclaving at 15 lbs. pressure for 12 minutes.

Note: A-D-M Prob. B212.6, 1949, white rats, 18 percent Protein; equalized feed intake; 42-day testing period.

fairly good correlation between such things as water dispersibility of protein, urease (measured by increase in pH), thiamine, water absorption, and color for soybean oilmeals processed day in and day out in the same plant with equipment operating as uniformly as possible each day. The same cannot be said of meals of unknown processing history. It is also true in most instances that one cannot use the analytical criteria developed for one processing plant as policing tools for good meal in another soybean plant, even though identical equipment is used in both plants.

Table 3 contains some pertinent data from our 1949 amino acid studies with raw and cooked soybean oilmeal. This study ran for 42 days, using standardized young male white rats as experimental animals. The protein assay diet was adjusted to 18 percent of protein, and the feed intake was equalized. In lots 2 through 7, the soybean material was unheated defatted soybean oilmeal. For lots 8 through 13, this same raw meal was cooked by autoclaving in the laboratory at 15 pounds pressure for about 12 minutes. The soybean oilmeal fed to lot 14 was our regular daily production of commercial meal made at our continous solvent extraction soybean plant operating then at Chicago, Illinois.

These studies show that the addition of 0.3 percent of DL methionine to lot 5 corrected the only deficiency apparent in the raw, unheated soybeans. At least, the performance in terms of protein efficiency was the same from adding methionine as that obtained by cooking the soybeans, as in lot 8. The amino acids used in this study, with levels indicated, were as follows:

	Percent
L lysine	.5
DL methionine	.3
DL tryptophan	.1
DL histidine	.2
DL phenylalanine	.3
DL leucine	.4
DL isoleucine	.2
DL threonine	.3
DL valine	.3
L arginine	.1

No other amino acid in the list of 10 considered to be essential, except methionine, corrected the nutritional deficiency in the raw soybean oilmeal. It is interesting also to note that raw meal plus methionine, as in lot 5, and the laboratory cooked meal fed to lot 8, as well as lot 11 receiving the cooked meal and methionine, are, for practical purposes, identical in protein efficiency and equal to the commercial meal fed to lot 14. Several of the lots in this study were equal in protein efficiency, or slightly superior, to the control lot (lot 1) fed dried skim milk as the sole source of dietary protein. Incidentally, the amount of soybean oilmeal used (as sole source of protein) was 37.5 percent in each soybean diet fed in this study (Prob. B212.6).

We interpret these results from our amino acid studies, as well as other similar results which we have obtained many times, to mean that raw or insufficiently cooked oil meal has an impaired protein efficiency or impaired feeding value in terms of its growth potential because one or more of the essential amino acids, presumably methionine and/or cystine, are at least partially unavailable to the animal during its normal digestion and assimilation period. We also conclude that these data disprove the theory that a number of investigators have advanced over the past several years—that raw soybeans contain toxic or inhibiting factors. Experimental work, apparently substantiating or refuting the toxicity or inhibitor theory, is excellently reviewed by Liener([11]). Our stand on this subject, as well as the belief of several others, is expressed and confirmed in a rather recent report by Borchers([5]).

Another factor which has improved soybean oilmeal, as a result of extensive research in processing methods, has been the development of a dehulled, properly cooked soybean oilmeal. This dehulled meal is commonly known in the industry as 50 percent soya. It analyzes 50 percent protein or better, and about 3 percent fiber, as contrasted to 44 to 45 percent protein and some 7 percent fiber for the regular full-fiber 44 percent solvent-extracted soybean oilmeal. The 50 percent meal has become very popular in the States for use in high energy broiler and high-energy laying feeds. In several feeding tests with chicken broilers we found that, on an average, the 50

percent soya was worth in excess of $60.00 per ton more than the full-fiber 44 percent soybean oilmeal, on the basis of the extra pounds of broiler meat produced by the ration containing the 50 percent meal. From recent experiments at Cornell University, Hill and Renner([10]) reported that the metabolizable energy of the 50 percent soya was 1150 and the 44 percent meal was 1,020 calories per pound.

According to a considerable amount of experimental work and practical application here and abroad, especially in Germany (Province of Duren), trichloroethylene is definitely not a safe solvent to be used for processing soybeans. Trichloroethylene-extracted soybean oilmeal can be highly toxic to cattle, horses and sometimes sheep, as well as guinea pigs and dogs. At the same time in no instance on record has hexane-extracted soy flour or soybean oilmeal been at all harmful to humans or to livestock or poultry as the result of the process or solvent used in producing the flour or meal. (A considerable amount of the work along this line is reported by Pritchard *et al*([14]).

Cottonseed Meal([2]) ([6])

Tremendous strides have been made over the past several years by a number of people in improving the nutritive value of cottonseed meal for poultry and swine. The principal obstacles during previous years were its high content of free gossypol and measurable damage to its protein from over-heating during the processing of the meal. Gossypol is a major pigment of cottonseed and has been responsible for cottonseed meal's depressing

TABLE 4
Effect of autoclaving on the nutritive value of ether-extracted cottonseed meal

Treatment	*Protein efficiency*
Unheated	1.99
Autoclaved, 30 min. at 120°	1.58
Autoclaved, 60 min. at 120°	1.08
Autoclaved, 120 min. at 120°	.28

Source: H. S. Olcott and T. D. Fontaine, *J. Nutrition 22,* 123 (1946).

effect on growth of chickens when used at high levels, as well as impairing hatchability and discoloring the yolks eggs when they are stored for any considerable length of time.

At the Third Conference on Cottonseed Processing as Related to Nutritive Value, held at New Orleans in November 1953, the following statements were passed as resolutions:

"Results presented thus far indicate that chick and broiler rations containing cottonseed meal and soybean meal in equal proportions on a nitrogen basis, are equal or superior to rations based on either cottonseed meal or soybean meal alone, when the cottonseed meal has 0.04 per cent or less of free gossypol and 75 per cent or more of nitrogen solubility in 0.02N NaOH solution. Preliminary indications are, insofar as free gossypol is concerned, that cottonseed meals having 0.04% or less of free gossypol can be fed in unrestricted proportions in balanced diets for chicks, broilers and swine."

An improved method was developed recently for determinating total gossypol in cottonseed and cottonseed meal.([15]) The advantages claimed for this proposed new method are its simplicity, accuracy, reproducibility, and expediency.

Linseed Oilmeal

A large percentage of the available supplies of linseed oilmeal—both in the United States and abroad—is used in feeds or as a feed for ruminants, namely, dairy cattle, beef cattle, and sheep. Linseed oil was extracted initially from flaxseed by mechanical means. At first this processing was crude. Then came hydraulic and expeller processing. After that—about 1949—the continuous method of solvent extraction was adapted to linseed in the United States. This initial commercial production of solvent-extracted linseed oilmeal was preceded by about 12 years of experimental testing at agricultural experiment stations and within the industry. These experimental studies proved beyond doubt that a properly processed solvent extracted linseed oilmeal (using hexane as the solvent) was quite as good for livestock feeding as mechanically pressed meal.

Table 5 gives the results of a rather classical experiment with beef cattle in which hydraulic meal was compared with solvent-extracted linseed oilmeal with respect to daily gains, selling price, dressing percent, and carcass grades of the cattle.

TABLE 5
The effect of linseed oilmeal on the finish of yearling steers

Eight steers per lot, fed 219 days	Unit	Hydraulic linseed oilmeal	Extracted linseed oilmeal	Ext. linseed meal and crude extracted linseed oil	Ext. linseed oilmeal and vitamin F conc.[1]	Ext. soybean oilmeal and crude ext. linseed oil
Avg. initial weight per head	Pound	604	607	601	597/	601
Avg. daily gain per head	Do.	2.12	2.09	2.09	1.99	1.87
Avg. daily feed per head:						
Shelled corn (14 percent moist.)		13.31	13.25	13.48	12.97	11.87
Protein supplement		1.50	1.46	1.46	1.46	1.28
Linseed oil	Gram	—	—	35.21	—	37.61
Vitamin F conc.	Do.	—	—	—	6.53	—
Alfalfa hay		4.78	4.78	4.78	4.78	4.86
Mineral mixture[2]		.03	.03	.03	.03	.03
Block salt		.03	.03	.03	.04	.02
Chicago selling price	Dollars Per lb.	12.25	12.25	11.75	12.00	11.00
Dressing percentage	Percent	62.2	62.7	62.1	61.7	62.6
Carcass grade:						
Prime	Gram	0	3	1	0	0
Choice	Do.	6	3	3	5	1
Good-choice	o.	1	2	3	2	3
Good	Do.	1	0	1	1	3

1. Certain unsaturated fatty acids from linseed oil.
2. Mineral mixture—Ground, raw limestone, 60 lbs.; special bonemeal, 37.94 lbs.; iron oxide, 2 lbs.; copper sulfate, 0.02 lb.; potassium iodide, 0.04 lb.

Note: Results of an experiment at the Iowa Agricultural Experiment Station June 15, 1938, to January 20, 1939 (project 605).

It has been generally concluded from this and many other cattle feeding tests that the "bloom factor" in linseed is due to its gum or mucilaginous substance, sometimes referred to as "mucin."

It has been known for many years that raw flaxseed contains a cyanogenetic glucoside, linamarin, from which HCN is liberated by the enzyme linamarase. This enzyme is completely destroyed during expeller processing, and, with the present

solvent extraction in the United States, the process used includes a special cooking operation that completely dissipates the cyanogenetic glucoside and inactivates the enzyme so that our solvent-extracted linseed oilmeal of regular production is negative in potential HCN or in prussic acid liberation.

Peterson([13]) reviews the controversy among a few investigators on a possible toxic or growth-depressing factor for poultry in linseed oilmeal versus advocates of the mucin in the meal being responsible for its depressing effect. In our laboratory we have never been able to confirm the results of Kratzer and McGinnis ([13]). However, we have often been able to confirm results of the Canadian workers ([13]) showing that the mucilage in linseed oilmeal is largely responsible for its objectionable features when fed to poultry. We have also demonstrated that the tolerance of growing chicks for linseed oilmeal can be at least doubled—that is, the level can be increased from 2½ to 5 percent in a complete ration—without the usual disturbing features of sticky, wet droppings and depressed growth by incorporating the linseed in the ration in the form of linseed grits (crumblized pellets) or by having the poultry ration fed as pellets or grits.

Peanut Meal

Peanut protein seems to be at its best biologically when it is raw. Yet, it will withstand mild heat treatments during processing, such as in solvent extraction or hydraulic pressing, without damaging the protein. Even autoclaving at 15 pounds pressure for 30 minutes affects the protein quality only slightly. However, peanuts subjected to commercial roasting or expeller (screw-press) pressing causes measurable damage to the biological value of the protein. Lysine is the first amino acid that is damaged. It is assumed that if peanut meal were heated excessively, methionine and/or cystine would be the next in line to be damaged. Considerable care should be taken during processing of peanuts to avoid overheating of the meal, since its protein does not contain a surplus of lysine—certainly none to spare—and since the peanut has a borderline content of methionine and cystine, even in its raw native state ([11]).

Miscellaneous Oilseed Meals

Sunflowerseed Meal. Processing methods employed in the

extraction of oil from sunflower seeds have marked effects on the nutritive value of the meal, particularly for poultry and swine. A maximum amount of hull should be removed from the seed prior to the extraction of the oil, and the decorticated meats should be subjected to a minimum amount of heat during the extraction process to avoid damage to the protein.

Rapeseed Meal.—Rapeseed is credited with a goitrogenic factor. It is believed that its precursor is mustard oil, allylisothiocyanate. The bound glucoside is called "gluconapin." The enzyme "myrosinase," unless inactivated, liberates mustard oil from this glucoside. It is claimed that the toxicity of repaseed meal can be considerably reduced, or practically eliminated, by processing it at controlled temperatures and reduced moisture (8 percent).

Mustardseed Meal.—Mustardseed also contains mustard oil in the form of the toxic glucoside, "sinigrin." Mustardseed or mustardseed meal can be rendered safe for animal consumption by special cooking or steaming during or after oil removal. However, the rather strong taste and aroma of mustardseed meal usually limits its use to 5 to 10 percent in rations for poultry and swine. A properly processed mustardseed meal has been fed to dairy cows in a dry form mixed with other concentrates at a level of 3 to 5 pounds a day without any adverse effects upon the milk.

Fish Meal

In the production of fishmeal, the fish may be precooked by either of two methods, commonly referred to as the "wet" and the "dry" processes. The wet process consists of grinding the fish to a slurry and cooking for around 30 minutes under steam pressure up to 15 pounds. In the dry method the ground fish is cooked dry in steam-jacketed cookers at temperatures around 212 to 230 degrees F.

Three types of driers are used, or have been used, in drying fishmeal: (1) Vacuum driers operated at temperatures around 100°F; (2) steam-jacketed driers operated at temperatures around 212°F; (3) hot-air driers operated at temperatures between 300 to 600°F. In some of these hot-air driers the heated gasses from the flames may come in direct contact with the material being dried. This process is called "flame" drying.

A review of a considerable amount of literature on fishmeals

as a source of supplementary protein for poultry and swine shows that the factors of greatest importance are spoilage before drying and temperatures used during the drying process. The species of fish and the cooking process—whether wet or dry—are considered by many experts to be of minor importance. There does not seem to be much doubt but that "flame" drying of fishmeal causes considerable damage to the biological value of the fish protein. This has been proved so many times that a few years ago the U.S. Bureau of Fisheries recommended that flame drying of fishmeal be discontinued.

The data in table 6 consist of the results obtained at the University of British Columbia([3]), in testing the effect of drying temperatures on folic-acid content of herring meal. The commercial meals were flame dried and the low-temperature meals were made by drying the press cake in a current of air maintained at 100° to 110°F. Folic acid content of the low-temperature meals was 4.1 and 4.7 micrograms respectively (A and B) per gram, and for the commercial flame-dried meals the folic-acid content was 0.29 and 0.27. The poor growth of the chicks on the flame-dried commercial fishmeal suggests that the protein was considerably damaged by overheating.

TABLE 6
Effect of processing on nutritive value of herring meal

	Average weight of chicks	*Relative nutritional value*
	Grams	*Percent*
Low temp. Meal A	217	100
Commercial Meal A	163	75
Low temp. Meal B	210	97
Commercial Meal B	155	71

Source: "Effect of Drying Temperature on the Folic Acid Content of Herring Meal," by J. Biely, B. March, and H. L. A. Tarr, University of British Columbia, *Science 116:* 249 (1952).

On an average, most of the good fishmeals in the United States analyze 60 percent and higher in protein. Some meals, especially herring, will analyze 70 percent and over in protein.

When we find a fishmeal testing much below 55 percent in protein we are suspicious that it is either a low-grade fishmeal, such as shrimp or crab meal, or it could be one of our good fishes adulterated or blended with a low-grade fish byproduct or foreign material.

Dr. C. R. Grau, University of California, has recently reported on the biological availability of amino acids in feed-stuffs(9). He uses charts to present his data on the growth rates for chicks in a lysine bio-assay for 4 different fishmeals. He also plots the content of amino acids in these fishmeals—both as to total and available. One fishmeal was purposely overheated. Growth rates varied from 0 to 6.6 percent for the fishmeals used in this comparison. The overheated meal, of course, was at 0, with its arginine completely unavailable, and the lysine about 20 percent available. Besides fishmeal, Grau also includes in his report some work he has done on soybean oilmeal, sesameseed oilmeal, cottonseed meal, and meat-and-bone meal.

Fish Solubles

The feed industry has, in general, considerable faith in liquid solubles from commonly processed fish as a source of one or more unidentified factor(s) for growth and reproduction in rations for poultry and swine. Fish solubles are available as a condensed or liquid product, a product made by drying liquid fish solubles on some carrier, such as soybean oilmeal or millfeed. At least one product is claimed to be a pure dried soluble plus dried fish liver and glandular meal. Liquid fish solubles analyze about 50 percent solids and usually some 32 percent protein. Blended products of fish solubles on a carrier have varying analyses according to the concentration of the solubles and the carrier used. As a rule, fish solubles are not much counted on as a concentrated source of high quality fish protein. Then, too, fish solubles have been criticized at times for lack of uniformity in content of growth and reproduction factors because of processing variables. There are not many scientific data to show whether the desirable factors in fish solubles are stable or unstable to such processing variables as heat, acids, alkalies, and the pH of the liquid or dried product.

Nevertheless, many specialists believe that there is a considerable variation between different kinds and batches of fish

solubles in content of the desired unidentified growth and hatchability factor(s). The reasons for these variances are not clear at this time.

Particle Size

Grinding versus chopping of hay and roughage.—Rather extensive experiments conducted with dairy cows have shown that grinding good roughage is not usually profitable and that such materials when finely ground may actually be detrimental to cows. It seems that when hay is ground very fine it does not stay long in the rumen but goes on unchanged into the true stomach. The stomach has no facilities for softening the hay so it continues on into the intestinal tract causing considerable irritation of the intestinal mucosa. Actually, in these experiments, normal feeding of good bulky hay resulted in the production of 7.5 to 11% more butterfat than when the cows were fed finely ground hay. The average differences in butterfat tests amounted to 0.32 percent in favor of normal feeding, that is, feeding good quality, rather coarse or bulky hay.

Fine versus coarse grinding of grains.—The fineness of grinding the grains and the grain concentrate portion of the ration is also worth considerable thought. Experiments at a northwest State agricultural experiment station showed that the fineness of grind of the grain did not affect the weight of the cows nor the digestibility of the ration, but that coarsely ground grain was more palatable than finely ground grain. Cows fed coarse grain produced 14.65 pounds more milk and 0.12 pound more fat during the experimental period than those receiving grain that was finely ground. A somewhat smaller amount of ground grain was required to produce 100 pounds of milk than was the case with the fine-ground grain. These differences in grain and roughage have been demonstrated mostly with dairy cows.

Pelleting Grasses and Legumes

According to most of the tests that have been reported(7), the pelleting of roughage may be expected to give increased rate and economy of gain in high-roughage-type rations. The work at Illinois (Dixon Springs Experiment Station) illustrated differences in the nutritive value of various roughages, even when

pelleted. Alfalfa hay pellets gave faster and more efficient gain than timothy-alfalfa pellets or Sericea Lespedeza hay pellets. What was said above about the objection to fine grinding of roughage seems also to apply to pellets or cubes. In a study(4) with sheep, grass hay was fed in chopped form as compared with cubes made from medium to finely ground hay and from very finely ground hay. The hay in the long or chopped form excelled in digestibility of dry matter, crude fiber, crude protein, cellulose, and nitrogen-free extract. Cubed medium-ground hay was next and the fine-ground hay in cube form was decidedly inferior.

TABLE 7
Effect of fineness of grind of alfalfa on performance of lambs fed pelleted feeds

Item	*Grind of alfalfa*[1]	
	1/16 inch	*1/4 inch*
	Pounds	*Pounds*
Average initial weight	70.0	68.7
Average final weight	89.5	91.3
Average daily gain	.433	.502
Feed per 100 pounds of gain	759.0	756.0

1. Pelleted rations consisted of 50 percent corn, 50 percent alfalfa; plus 2 pounds of trace minerals and 10 pounds of limestone per ton.

Source: General Series paper 671, Colorado Agricultural Experiment Station, Feb. 27, 1958, p. 17.

TABLE 8
Effects of feeding baled, wafered, or pelleted alfalfa hay to dairy cows

	Unit	*Form of Alfalfa Hay*		
		Baled	*Wafered*	*Pelleted*
Feed consumed	Pounds	797.2	833.2	811.8
Body weight	Do.	1195.6	1212.9	1190.6
Butterfat	Percent	4.13	4.15	4.0
Total milk produced	Pounds	899.74	887.06	903.93
4 percent FGM	Do.	848.83	857.14	853.24

Source: Oregon State College Reprint, May 1958.

Table 7 gives the results of the grind of alfalfa on the performance of lambs fed pelleted feeds. There were two grinds of alfafa used in this Colorado test—one was $\frac{1}{4}$-inch and the other was 1/16-inch. The $\frac{1}{4}$-inch grind of alfalfa was far superior to the 1/16-inch grind. At the present time there is considerable interest in the compressing of hay into a wafered or pelleted form as opposed to the baling of hay such as is commonly done on many farms. Table 8 gives the results of a test conducted at the Oregon State College with baled, wafered and pelleted alfalfa hay fed to dairy cows. There is no apparent difference between the three physical forms of hay with regard to feed consumption, actual or 4 percent fat corrected milk production, or body weight of the cows. However, the feeding of pelleted hay (ground through a 5/16-inch screen) resulted in a statistically significant reduction in butterfat production, as compared with either baled or wafered hay. There was no difference in milk or butterfat production between the cows fed either baled or wafered hay.

Summary

From the data presented, it may readily be seen that processing procedures can exert definite effects, both beneficial and detrimental, on ingredients that are intended to be used in the manufacture of feeds for livestock and poultry. Regardless of the quality or nutritive value of an ingredient in its raw or native state, proper or improper processing can alter these characteristics, either to improve or cause deterioration.

It has been shown that heat, when used at optimum levels in conjunction with properly controlled moisture, time intervals, and other processing variables, may have a beneficial effect on the nutritive value of various protein meals. On the other hand, the improper use of heat during processing can result in a definite deterioration of the protein quality of many of these meals. In addition, improper use of heat can destroy the vitamins, unidentified growth, and reproductive factors, and other desirable nutrients in feed ingredients.

Granulation (particle size) of one or more of the ingredients in a feed mixture for ruminants can exert a definite effect on the animal and its production. This effect may result from an alteration in palatability of the mixture or from any influence (mostly

physical in nature) that an ingredient or feed mixture has on digestibility (especially rumen function) within the animal's body. Both beneficial and adverse effects have been observed from feeding certain ingredients and feed mixtures in pelleted or compressed form.

As the world population increases, resulting in a greater demand for meat, milk, eggs, wool, and other items produced only by livestock and poultry, processing research will be called upon more and more to produce ingredients with a minimum of impairment in their nutritive value. A look into the future reveals a definite need for marked improvement in the efficiency of production, if we are to meet this increasing demand for these products. Any deficiency in the nutritive value of the ingredients used in the feeding of our poultry and livestock serves only to reduce efficiency of production. In addition, those ingredients which can be used directly for human food must be processed in such a way as to improve both their acceptability and nutritional value.

REFERENCES

(1) Altschul, A. M. (editor) PROCESSED PLANT PROTEIN FOODSTUFFS, Academic Press, Inc., 111 Fifth Avenue, New York 3, N. Y. (1958)

(2) Altschul, A. M.; C. M. Lyman and F. H. Thurber, in PROCESSED PLANT PROTEIN FOODSTUFFS (A. M. Altschul, editor), Chapt 17 "Cottonseed Meal", pp 469—534, Academic Press, Inc., 111 Fifth Avenue, New York 3, N. Y. (1958)

(3) Bieley, J.; B. March and H. L. A. Tarr, "The Effect of Drying Temperature on the Folic Acid Content of Herring Meal", SCIENCE *116*: 249-250 (1952)

(4) Blaxter, K. L. and N. McC. Graham, "Effect of the Grinding and Cubing Process on the Utilization of the Energy of Dried Grass", J. AGRI. SCI. *47;* 207—217 (1956)

(5) Borchers, R., "Effect of Dietary Level of Raw Soybean Oil Meal on the Growth of Weanling Rats", J. NUTR. *66;* 229—235 (1958)

(6) Curtin, L. V., "Use of Low Gossypol Cottonseed Meals in Swine and Poultry Feeds", FEEDSTUFFS, Vol. 26, No. 48, pp 49—66, November 27, 1954.

(7) Elrod, R. C., "Pelleting Roughage, Grain or Complete Rations for Beef and Dairy Cattle" in Report on Fifth Technical Alfalfa Conference held at Fort Collins, Colorado August 15, 1958. (Copies of this report may be obtained by writing the American Dehydrators Association, 1015 Dwight Building, Kansas City 6, Mo.)

(8) Fixsen, Margaret A. Boas, "The Biological Value of Protein in Nutrition", NUTR. ABST. AND REV. *4:* 447—459 (1935)
(9) Grau, C. R., "Biological Availability of Amino Acids in Feedstuffs", in papers presented at the Annual Meeting of the Animal Nutrition Research Council, October 15, 1958, Washington, D. C.; reprinted from the December 6, 13, 20 and 27, 1958 and January 3, 1959 issues of FEEDSTUFFS
(10) Hill, F. W. and R. Renner, "Studies of the Metabolizable Energy of Soybeans and Soybean Products for the Chick", POULTRY SCIENCE *37*, 1212 (1958)—abstract
(11) Liener, I. E., in PROCESSED PLANT PROTEIN FOODSTUFFS (A. M. Altschul, editor), Chapt 5, "Effect of Heat on Plant Proteins", pp 79—129, Academic Press, Inc., 111 Fifth Avenue, New York 3, N.Y. 1958.
(12) Markley, K. S. (editor) SOYBEANS AND SOYBEAN PRODUCTS, Vol I (1950) and Vol II (1951), Interscience Publishers, Inc., 250 Fifth Avenue, New York 1, N. Y.—or Interscience Publishers, Ltd., 2a Southampton Row, London W. C. 1
(13) Peterson, Seth W., in PROCESSED PLANT PROTEIN FOOD STUFFS (A. M. Altschul, editor), Chapt 21, "Linseed Oil Meal", pp 593—617, Academic Press, Inc., 111 Fifth Avenue, New York 3, N.Y. (1958)
(14) Pritchard, W. R.; C. E. Rehfeld; N. S. Mizuno, J. H. Seutter and M. O. Schultze, "Studies on Trichloroethylene-Extracted Feeds" (in 7 parts), AMER. J. VET. RES. *17*, pp 425—454 (1956)
(15) Smith, F. H., "Spectrophotometric Determination of Total Gossypol in Cottonseed Meal and Cottonseed Meats", J. AMER. OIL CHEM. SOC. *35,* pp 261—265 (1958)

Quality-Feed Manufacturing

By J. L. KRIDER
Vice President, Central Soya Co., Inc., and McMillen Feed Mills

THE stature of the U.S. feed industry, as indicated by the production of 40 million tons of formula feeds in 1958, places great responsibility on our growing industry.

Research

Acceptance of this responsibility in *quality-feed manufacturing* is exemplified by the great amount of research being done in our industry to develop the most efficient, economical animal feed formulas. The American Feed Manufacturers have a Nutrition Council with 74 feed manufacturers represented out of a total of 87 members. The 74 members who are responsible for the nutrition research and animal feed formulation in 1958 reported:

... 623 years college and experiment station work
... 1,074 years of feed industry experience
... 86,122 four-footed animals fed annually
... 3,804,597 head of poultry fed annually
... 11,231 experiments conducted annually

There were 1,410 total scientific personnel engaged in biological research, quality control, and feed formulation, or an average of 19 scientists per feed manufacturer.

In addition, many scientists in industries that supply ingredients, as well as college and experiment station personnel, contribute to the progress of formulating and manufacturing quality feeds.

Education

The Management Survey Committee of the A.F.M.A.

Nutrition Council has summarized livestock and poultry recommendations from as many as 200 authoritative sources, including the colleges, experiment stations, U.S. Department of Agriculture, and the feed industry. Uniform management recommendations have been published and widely distributed to aid in getting top performance of animals fed balanced rations.

Complexity of Feed Manufacturing

Our approach to manufacturing quality feeds in 144 forms and packages at one plant, using 121 ingredients, is probably similar to other manufacturers. These feeds and packages include mash, crumbles, and various sizes of pellets. The list includes chicken feeds for baby chicks, pullets, layers, breeders, broilers, caponettes, and roasters; also, feeds for turkeys, swine, ruminants, horses, dogs, rabbits, etc.

The feeds may contain antibiotics, growth stimulants, medicaments, hormones, etc., as indicated by research. We attempt to apply the results of nutrition research, quality control, engineering know-how, production efficiency, and marketing knowledge to our feed operations using various types and qualities of ingredients.

The following steps are taken in the manufacture of quality feeds in a new "auto-syntronic" feed mill recently built by our company.

It can produce 200 tons of formula feeds per 8 hours with 12 workers in the mill plus an office staff of 8. By using two 8-hour shifts, it can produce over 100,000 tons annually.

The plant is designed for rail or truck transportation and for producing feeds in meal, crumble, or pellet form, bagged or bulk.

Ingredients are purchased for the plant on the basis of rigid specifications set up by research scientists and quality control personnel. The incoming grains, grain byproducts, proteins, etc., are *sampled* on arrival and these samples submitted to certain analytical procedures before they are approved for use in feed manufacturing.

Quality Tests of Ingredients

Routine chemical analysis and other specified tests are

made in laboratories to check (a) incoming ingredients, and (b) finished feeds. Some tests are made in laboratories in the plants while other analytical procedures are done in a central laboratory. These include tests for moisture, protein, fat, fiber, nitrogen-free extract, ash, certain minerals, vitamins, and, in some cases, for undesirable substances. The latter include urease in soybean oilmeal, magnesium in calcium carbonate supplements, etc.

Receiving

A mechanical belt conveyor, located beneath truck and car dumps, discharges grains and ingredients into a pneumatic suction conveyor system, which takes them into the mill. A magnetic separator, over the belt conveyor, pulls out all tramp metal. The air and grains, or ingredients are then separated in a cyclone. The grains, or ingredients pass through a scalper, and the air goes through a stocking dust filter. From the scalper the stream goes to a separate pressure fluidizing pneumatic system.

Storage

Multiple pneumatic conveyor lines move the fluidized stream to storage bins for mixing, or to whole grain bins for grinding. The 4 pneumatic lines elevate to a height in excess of 100 feet, where turnheads direct the flow to spouts discharging into any of 29 bulk storage bins. The cylindrical bins are single compartments, approximately 12 feet in diameter and 40 feet in height. The rectangular bins have 4 compartments and are approximately 12 feet square and 40 feet high.

Mixing

Mixing operations are carried on in 3 separate stages. Mixing of high percentage ingredients and selected liquids; mixing of trace or low percentage ingredients; and a final blending of the remaining liquids before bagging.

Prepunched select-o-weigh cards, which carry the formulation for the desired feed, are placed in a fixed card "reader" that actuates the master electronic control panel for addition of both high and low percentage ingredients.

In the case of high percentage ingredients, the panel "turns on" screw-type feeders located beneath each of the ingredient bins. These feeders deliver ingredients one at a time to a 2 1/2-ton hopper scale above the main mixer. When the desired amount of ingredient has entered the scale, the feeder is automatically shut off. The scale then checks itself. If, for any reason, the desired amount did not enter the scale, the remaining feeder sequence is suspended until the proper amount of ingredient has been added. When the card has been completely "read," and the hopper scale contains the desired ingredients in the amounts called for in the formulation, the hopper scale discharges into the main mixer.

A separate and similar proportioning operation is carried on simultaneously for the mixing of low percentage ingredients.

Vibrating feeders deliver the desired amounts of low percentage ingredients to a 50 pound hopper scale, which, when filled with the correct amounts of selected materials, discharges into a miniature mixer. The charge from the miniature mixer is air-conveyed to the main mixer and the two charges are blended together. Selected, liquid ingredients are also added in this primary blending stage.

When the required blending time has elapsed, the main mixer empties into a feed surge hopper. While the mixers are operating, the scale hoppers are "weighing" the next formulation. Thus, there are three feeds in suspension during primary blending; one being weighed, one being mixed, and the third in a feed surge hopper beneath the mixer.

Grinding

From bulk grain bins, whole grains can be gravity fed to a 75 h.p. hammermill, where they are ground and then air-conveyed to ground grain bulk storage bins. Where whole grains are called for in some feeds, the grinding operation can be bypassed, and the grain conveyed directly to ingredient storage bins.

Blending and Bagging

From the surge hopper beneath the primary mixer, the feed is then air-conveyed to the top of the mill where it is

again scalped and discharged into feed surge bins. From these bins the feed flows through gravimetric feeders to the final blender. It is at this point that remaining liquids are metered into the mixture.

Addition of selected initial liquids is accomplished by electronically proportioned metering into a 30-gallon liquid surge tank. From this tank, through the use of interlocked pressure switches and solenoid valves, the premixed liquids are handled as any other ingredient on the master programming console.

The adding of final liquids is electronically controlled. Preset proportion dials call for a definite amount of the final liquids. The electro-hydraulic Askania metering system delivers the desired amount to the final mixer, and at the same time, the delivered amount is indicated and recorded on the master control console.

The liquids involved in the dual blending and mixing operations are vitamin feeding oils, fats, condensed fish solubles, and molasses. Thermostatically-controlled temperatures in the system vary from 80° F. during storage to as high as 180° F. during delivery and mixing.

After final blending, the feed may be bagged off through automatic bagging scales, bypass the bagging scales and be sent to bulk feed bins for truck or car loading, or be conveyed to pellet supply bins.

Pelleting

Feed to be pelleted or crumbled discharges from overhead supply bins to a 100 h.p. pellet mill, then through a pellet cooler. Following cooling, the pellets are elevated, pass through a feeder to, or can bypass, a crumblizer. Following pelleting or crumblizing, the feed is graded to assure a dust-free pellet or a uniform-sized crumble, with fines and overs going back for reworking.

The pelleted or crumbled product then goes to finished pellet bins or to feed surge bins for use in formulations that require pellets.

Loading Out

Loading out facilities include both bag and bulk forms

for truck or rail shipment.

Bulk truck loading is accomplished through overhead bins positioned over a 50 foot, 50 ton truck scale. Bulk rail loading is through gravity discharge of feeds elevated after the blending and bagging operations.

Bagged feeds mostly in either 50 or 100 pound sacks or in bulk, concentrates and complete feeds go from the manufacturing plant in company owned or dealer trucks to the dealer's mill to serve farm customers who raise livestock and poultry in the most efficient, economical way possible.

In conclusion, many factors of a manufacturing operation produce the desired quality control. These are:

1) Quality personnel
2) High quality research and quality control personnel
3) Built-in quality through proper engineering and equipment
4) Proper identification and labeling of quality incoming ingredients, mixtures in mixing operation, and the finished product ready for delivery to dealers and farmers

In manufacturing quality feeds, our industry is producing and selling a specific amount of animal production . . . not just an accumulation of feed ingredients. One hundred pounds of quality feed, depending on the purpose for which it is fed, may produce 400 pounds of milk, 20 pounds of butter, 300 eggs, 35 pounds or more of broiler meat, 28 pounds of turkey, 25 or more pounds of pork, or 10 pounds of beefsteak.

In the final analysis, it's performance that counts!

Quality Feeds Yield Good End Products—Improved Poultry and Egg Products

By HANS LINEWEAVER
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THE rapid gain in poultry consumption that has occurred in the United States recently has been accompanied by changes in both production and processing methods. Better quality feeds, improved management, and selective breeding have made marked changes in the production of poultry and eggs, most notably in growth rate and feed efficiency. For example, in 1940 it required 4.9 pounds of feed per pound of gain, whereas in 1957 the industry average was 3 pounds per pound of gain. We need to know whether the important improvements in growth rate and feed efficiency have been accompanied by changes in quality of poultry and eggs. Do we get as much flavor from 3 pounds of feed as from 4.9 pounds? I shall discuss this more specifically later.

Certainly, present commercial products are good—they must be good to support a better than $3-billion industry in the United States where poultry meat production (including turkeys) increased 140 percent from 1940 to 1957 and egg production 52 percent, while population has increased only 31 percent (tables 1 and 2).

Important quality improvements have been made since the 1930's. Knowledge of feed factors, for example, has

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1. A laboratory of the Western Utilization Research and Development Division, Agricultural Research Service, U.S. Department of Agriculture.

TABLE 1

Poultry and eggs: Growth of the industry in the United States, 1940 to 1957

Product	*Increase from 1940 to 1957*	
	Per capita consumption[1]	*Production*[2]
	Percent	Percent
Poultry meat:	85	140
Chicken[3]	82	134
Turkey	103	169
Eggs	12	52

1. Population increased 31 percent during this period.
2. Based on live weight. Includes items exported, held over, and used by the military.
3. Including broilers.

TABLE 2

Egg products: Increase in utilization in the United States, selected years, 1939—58

[*Annual value of egg products in 1957 was $100 million*]

Year[1]	*Shell eggs going into*		
	Liquid and frozen	*Dried*	*Total*
	Percent	Percent	Percent
1939	4.3	0.8	5.1
1952	4.9	1.2	6.1
1956	5.4	1.6	7.0
1958	——	——	7.4[2]
Percent increase	25	100	37

1. Years selected because data are nearly free of war and other special influences.
2. Estimated.

permitted the virtual elimination of fishy flavor in turkeys and chickens. Uniform feeds, improved management, and/or breeding have led to greater uniformity in such

appearance factors as egg shell color, yolk color, skin color, and finish or fattening of birds—and hence to greater consumer satisfaction. Many cottonseed meals contain enough gossypol substances to cause serious yolk darkening if used improperly in the hen's diet. Thus feed can influence the quality of the product.

Quality Factors Influenced by Diet

Quality factors influenced by diet include flavor, stability, color, finish, fat composition, and possibly such others as juiciness, tenderness, and functional properties of eggs.

Stability of frozen turkey is less than that of chicken. Following the suggestion of Nutter and coworkers (1), studies at our laboratory have shown that this is due to the lower tocopherol content of turkeys than chicken, which results from lower efficiency of deposition of tocopherol by turkey than chicken (2,3). Ordinarily, turkeys are adequately stable, but if greater resistance to rancidity development is desired it can be obtained by supplementing the diet with tocopherol (2,3,4).

Finish, which reflects principally fat in the skin, can be improved by high-calorie, high-fat diets (5).

Color uniformity of poultry and of the yolk of eggs is desirable and is, of course, influenced by the dietary intake of xanthophylls. So far as is known the xanthophylls affect only the color (20). Uniform feed composition, especially with respect to xanthophylls, gives uniform yolk color.

Fat Composition of both birds and eggs reflects to varying degrees the composition of the diet. The egg fat composition can be changed only in the direction of greater unsaturation by addition of fat to a low or nonfat diet, whereas body fat *can* be changed to either more or less saturation (6,7). If fatty acid composition is important to the consumer it could be altered, but not without cost. The low fat content of young birds especially, and the presence of 20 percent linoleic acid in fat of turkeys and chicken (8) serve to make poultry a very attractive food nutritionally.

Juiciness and tenderness of poultry and functional properties of eggs have not thus far correlated with ordinary variations in diet composition.

Flavor of poultry has long been considered to be influenced by diet (9). The difficulties of making quantitative and qualitative flavor measurements, combined with the attempt of some investigators to study quite small flavor differences, are doubtless responsible for the present rather unclear picture of the relation between poultry feed and flavor.

Although some regard the cereal grains as sources of differential effects on flavor, various workers have reported none or only very minor differences in turkeys and chickens fed rations containing either corn, oats, barley, wheat, rye, or combinations of these grains (10, 11, 12). Small but significant differences were reported between birds fed a yellow corn, wheat, alfalfa, and soybean meal diet and a "synthetic" (casein and gelatin, cerelose, etc.) diet (13). These results indicate that grains are desirable dietary components from a flavor-effect point of view. On the other hand, we must for the present conclude that the kind of grain plays little or no role in flavor; hence there is no reason to discriminate, because of flavor effects, against any of the grains just mentioned.

Protein concentrates appear to have no important effect on flavor. However, fish meal that is not free of oil can cause fishiness, as has been amply demonstrated. Removal of fish oils from the diet 8 weeks before slaughter seems to assure freedom from fishiness (14, 15).

Vegetable concentrates such as soybean meal generally have not been reported to influence flavor. Cottonseed meal may cause dark yolks, but no flavor effect has been reported with diets containing less than 10 percent meal (28).

Additives of various types have been studied for their effect on flavor. Highly seasoned substances appear generally to have no effect on flavor. Garlic in the diet was reported to affect the meat flavor, but cloves, sage, allspice, celery, and monosodium glutamate even at a 20 percent level did not (16). These substances were in the diet for only 4 days before killing. Antibiotics and hormones added to the diet have had little or no effect on flavor, although the greater fat deposition caused by estrogen was thought to accentuate fishiness if present (14, 17, 18, 19). No correlation between flavor and the xanthophyll content of the diet was found (20). No effect of tallow or hempseed oil was found on egg flavor when fed up

to 28 percent levels; however, linseed oil and cod liver oil in the diet have been reported to produce an unpleasant taste in eggs (6, 21).

It appears that only the highly unsaturated fats of the linseed and fish oil type induce important off flavors in poultry and eggs. This is of special importance because fats have in the last few years become an economical source of calories for poultry feed. A number of studies on tallow and grease have been conducted to establish the safety of using various commercial fats in poultry feed. No flavor effects on poultry meat have been found by adding to the diet: 10 percent beef tallow; 3 percent choice white grease, yellow grease, and prime tallow; 3 and 6 percent No. 2 tallow; 5 percent tallow; 5 and 10 percent cottonseed fat and soybean fat; or 26 percent choice white grease (5, 22, 23). Stability, where studied, was not affected either.

Effect of Modernization on Flavor of Poultry

Modern feeds and management practices produce bird weights in 9 weeks that formerly took 14 to 16 weeks. People have frequently asked—which has more flavor—the modern broiler or the old-fashioned spring chicken? Three segments of the Agricultural Research Service of the Department of Agriculture have cooperated to test and compare the flavor of yesterday's chicken with today's. The results show the following:

(a) The modern broiler is as full flavored as its predecessor.

(b) The present fast growth is not detrimental to flavor.

In making these tests, two types of birds and two growing conditions were used.

The birds were a slow-growing strain of Barred Plymouth Rocks and a fast-growing, good-fleshing cross of New Hampshire males and Silver Cornish females.

Birds of each type were grown under two conditions—on range on a 1930-type diet, and in confinement on a modern-type diet.

There were marked differences in growth rates.

At 9 weeks the faster-growing birds on the modern diet were 60 percent heavier than the slow-growing birds on the

1930-type diet. When the slow growers were raised under modern conditions and the fast growers under 1930 conditions, the rates of growth were intermediate between these extremes.

Over 500 flavor comparisons were made. These included the following comparisons between old and modern-type chickens:

(1) Equal-weight birds, fried (several separate tests).
(2) Equal-age birds, fried (several ages).
(3) Equal-age birds, deboned and prepared in equal-size rolls so that cooking times were equal.
(4) Birds prepared by broiling.
(5) Birds prepared by microwave cookery.
(6) Birds prepared by roasting.

There were 20 individual tests or experiments consisting of either 15 or 32 tastings each. The taste panel members were asked to designate the bird with the most chicken flavor. The panel averages favored the old-type bird 9 times, the new type 7 times, and reported a tie 4 times (table 3).

TABLE 3
Flavor intensity comparisons: Modern (1956) and old-type (1930) chicken
[*Cooking methods used*: *oven fry, broil, microwave and roasting*]

Classification of material tasted	*Expts.*	*Times panel averages indicated*		
		Equal flavor	*More flavor in*	
			Modern birds	*Old-type birds*
	No.	No.	No.	No.
Equal size (unequal age), 3, 4, and 5-pound birds	10	2	4	4
Equal age (unequal size), 9, 10, 12 and 16 weeks	6	2	2	2
Equal age, deboned and made into equal-size rolls to equalize cooking time	4	0	1	3
Total	20[1]	4	7	9

1. Represents over 500 individual judgments.

Comparisons of flavor intensity were made under conditions designed to facilitate detection of small differences.

Since no differences in flavor of meat were found at either laboratory in birds cooked by the four methods, and since these birds are as nearly representative of their periods as can be produced, it appears that the modern bird has as much "chicken flavor" as the old-style bird.

Prompt evisceration of modern birds has eliminated visceral off-flavors and quality feeding has eliminated harmful factors from the diet.

The tremendous increase in per capita consumption of broilers—from about 2.5 pounds in 1947 to about 19 pounds in 1957—is undoubtedly due to several factors. But even so, such an increase must indicate that modern broilers are highly acceptable as far as flavor is concerned.

The inherent eating qualities of poultry and eggs produced by modern methods are evidently outstanding. Furthermore, and as is well known, the components contain amino acids and fatty acids that are nutritionally highly desirable. These facts, plus the high efficiency of feed conversion by the chicken, qualify chicken as perhaps our most valuable converter of grain to food products that are both highly attractive and highly nutritious.

Appendix

Types of Egg Products and Principal Users of Egg Products

Dried Eggs

Product	*Use*
1. Plain yolk powder	Donut mix, noodles
2. Sugar yolk powder	General bakery usage
3. Fortified whole egg powder	Sweet doughs (yeast raised donuts, sweet rolls)
4. Sugared whole egg powder	Cookies
5. Fortified whole egg powder (with sugar)	General bakery usage
6. Stabilized glucose-free (whole egg powder)	Government procurement
7. Spray dried egg white	Angel cake, meringue, etc.
8. Pan dried egg white	Candy

Frozen Eggs

1. Plain yolk	Noodles, baby yolk
2. Sugar yolk	General baking usage
3. Fortified whole egg with sugar solids	General baking usage
4. Salt yolk	Salad dressing
5. Salt whole egg	Mayonnaise
6. White	General purpose baking.

Egg Products Users

1. Wholesale and retail bakers
2. Noodle manufacturers.
3. Mayonnaise and salad dressing manufacturers.
4. Prepared mix manufacturers (cake, cookies, pudding, breading, icings, etc.) (Institutional and Household).
5. Confectioners.
6. Ice Cream.
7. Miscellaneous (baby yolk, frozen waffles, egg nog, shampoo, animal foods).

REFERENCES

1. Nutter, M. K., Lockhart, E. E., and Harris, R. S. The chemical composition of depot fat in chickens and turkeys. Oil and Soap, *20*, 231—254 (1943).
2. Mecchi, E. P., Pool, M. F., Behman, G. A., Hamachi, M., and Klose, A. A. The role of tocopherol content in comparative stability of chicken and turkey fat. Poultry Sci., *35*, 1238—46 (1956).
3. Mecchi, E. P., Pool, M. F., Nonaka, M., Klose, A. A., Marsden, S.J., and Lillie, R.J. Further studies on tocopherol content and stability of carcass fat of chicken and turkeys. Poultry Sci., *35*, 1246—51 (1956).
4. Criddle, J. E., and Morgan, A. E. Effect of tocopherol feeding on the composition of turkey tissue. Proc. Soc. Exptl. Biol. Med., *78*, 41—46 (1951).
5. Leong, K. C., Sunde, M. L., Bird, H. R., and Weckel, K. G. Taste panel evaluation of the effect of added fat on flavor of chicken meat. Poultry Sci., *37*, 1170—72 (1958).
6. Cruickshank, E. M. Studies in fat metabolism in the fowl. I. The composition of egg fat and depot fat of the fowl as affected by the ingestion of large amounts of different fats. Biochem. J., *28*, 965—77 (1934).
7. Feigenbaum, A. S., and Fisher, H. The influence of dietary fat on

the incorporation of fatty acids in body and egg fat of the hen. Arch. Biochem. and Biophysics, *79*, 302—306 (1959).
8. Goddard, V. R., and Godall, L. Fatty acids in food fats. Home Economics Research Rept. No. 7, U.S. Department of Agriculture.
9. Tibbles, W. Foods—their origin, composition, and manufacturing. London. Bailliere, Tindall & Cox (1912).
10. North, M. O. Influence of cereal grains upon quality of meat in turkeys. Wyoming Expt. Sta. Bull. 248 (1941).
11. Poley, W. E., Rosenquist, A., and Moxon, A. L. Effect of corn, wheat, and barley in the diet on the flavor of fried and roasted chickens. J. Agri. Res., *61*, 179—90 (1940).
12. Odland, L. M., Mayfield, H. L., and Page, L. The influence on palatability of certain grain combinations, fish solubles, and a vitamin B12 aureomycin supplement in poultry rations. Poultry Sci., *34*, 822—31 (1955).
13. Lewis, R. W., Sanford, P. E., Ericson, A. T., Harrison, D. L., and Clegg, R.E. Flavor and aroma of birds fed purified and standard diets. Poultry Sci., *35*, 251—53 (1956).
14. Marsden, S. J., Alexander, L. M., Schopmeyer, G. E., and Lamb, J. C. Starting diet as a factor in edible quality of turkeys. Poultry Sci., *31*, 451—58 (1952).
15. Asmundson, V. S., Jukes, T. H., Fyler, H. M., and Maxwell, M. L. The effect of certain fish meals and fish oils in the ration on flavor of the turkey. Poultry Sci., *17*, 147—51 (1938).
16. Newan, S., and Schaible, P. J. Effect of spices in feed on carcass flavor. Poultry Sci., *36*, 1145 (abstract) (1957).
17. Swickard, M.T., Montague, E.H., Dochterman, E.F., and Marsden, S. J. Palatability of experimental estrogen-treated turkey fryers. Poultry Sci., *31*, 126—29 (1952).
18. Stadelman, W. J., and Wilcox, R. A. The effect of thiouracil and diethylstilbestrol treatment of turkeys on storage quality of meat. Poultry Sci., *29*, 625—27 (1950).
19. Fry, J. L., Bennett, G., and Stadelman, W. J. The effect of age, sex, and harmonization on the flavor of chicken meat. Poultry Sci., *37*, 331—35 (1958).
20. Lewis, B. L., Harrison, D. L., and Sanford, P. E. Effect of xanthophyll on the palatability and fat stability of fresh and frozen broad-breasted bronze turkeys. Food Res., *23*, 7—16 (1958).
21. Albright, W. P., and Thompson, R. B. Variations of egg yolk color and characteristics produced by feeding and environment. Poultry Sci., *14*, 373—75 (1935).
22. Darrow, M. I., and Essary, E. O. Influence of fats in rations on storage quality of poultry. Poultry Sci., *34*, 427—31 (1955).
23. Arscott, G. H., and Sather, L. A. Performance data and flavor evaluation of broilers fed diets containing varying amounts of animal fat. Poultry Sci., *37*, 844—50 (1958).
24. Marsden, S. J. Feeds do affect flavor. Turkey World, p. 17 (June 1954).

Better Dairy Foods

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FOR milk and milk products to be acceptable to consumers they must have good flavor and attractive appearance, and be uniform from day to day. They should also have good keeping quality under normal use conditions. The responsibility for furnishing milk products of excellent quality rests jointly with the producer, the processor, and the distributor, backed up by the equipment and supply industries, and the public health regulatory officials.

As a representative of the supply industry you in the feed industry should be aware of the responsibilities in this regard assumed by other branches of dairying, but be specifically cognizant of your own responsibilities. It is doubtful if processors can do as much to improve quality *after* milking as the producer (and the feed industry) can do *prior* to milking.

First, the milk must be obtained from healthy cows. Milk from unhealthy cows frequently is not only of undesirable quality with regard to flavor, but substandard with regard to nutrition and disease. The herd itself, the stables, the milking parlor, the associated milk room, equipment, etc., must be clean. Milk must be cooled promptly to 40°F. and protected from dirt, sunlight, heat and severe cold.

What about the specific effects of feed?

Proper feeding of the dairy cow has much more effect on the amount of milk produced than upon the composition of the milk. There can be temporary compositional changes brought about by changes in feed practices, but they do not persist for long periods. For example, feeding high amounts of fat can temporarily increase richness of milk, but the

general conclusion is that the kind of feed does not greatly change the percentage of fat in the milk. In this instance, heredity is a much more important factor.

There can be changes in the character of the fat, too—hard fats in the feed will produce hard butter, and soft fats, soft butter; feeding exclusively on alfalfa hay can cause sticky or crumbly butter; or changes from dry feed to pasture, abruptly, can cause soft butter; and even feeding finely chopped forage may produce more unsaturated fat.

It has been found that the best milk is high in lactose and low in chlorides, but it is difficult to influence levels of these substances by feeding practices. Cows with mastitis frequently give salty milk, as do some cows when they are being dried off. Some cows inherit a tendency to produce salty milk.

Iodine and cobalt levels in milk are dependent upon the levels of these minerals in feed. In this country, goiter, due to iodine deficiency, is probably the most widespread of all nutritional deficiency diseases. Cobalt is the essential mineral for the production of vitamin B^{12} so important in growth and blood building mechanisms. Although the level of vitamin B^{12} in milk might be affected by the cobalt content of feed, the level in the human diet is more drastically affected by choice of foods.

Rickets is the classic disease caused by the deficiency of vitamin D, calcium, and/or phosphorus, but variations of these substances in feed do not reflect in the quality of the milk produced. Milk is improved with the addition of 400 I.U. of vitamin D per quart.

Vitamin A levels in feed do influence vitamin A levels in dairy products. Since the cow is solely dependent upon her feed for vitamin A and carotene, it is a recognized practice to add vitamin A to formulated feeds in order to satisfy her own needs, and to secrete this nutrient into milk for a part of man's needs.

A study conducted at Michigan State University over a 10-year period has shown that the high nutritive value of milk is not significantly affected by feed except perhaps for vitamin A. The study was sponsored, in part, by a grant from the National Dairy Council and was reported in a symposium on the Relationship of the Nutrition of Plants, Animals and Man

held in February 1955 at East Lansing, Michigan. Another conclusion from that study was that variations in the composition of milk are more related to breed differences and to stage of lactation than to feeding practices or soil fertility.

The aspects of quality that can be affected more generally by feeding practices can be grouped as palatability factors, as they affect the flavor, odor, and texture of milk and dairy products. A substantial majority of complaints about off-flavored milk are related to what cows eat.

Even sudden changes from dry feeding or old pasture to lush pasture can produce strong-flavored milk, and such changes should be made gradually. Many weeds contain certain highly flavored essential oils or fatty acids (wild onion, garlic, bitterweed, stinkweed). Fortunately weeds can be eliminated better today by using recently developed herbicides; new processing methods can remove weed flavors from milk fairly well if prevention methods fail.

Common feeding stuffs that cause off-flavors include: turnips, cabbage, rape and kale. Others with less distinctive flavors are green alfalfa, green sweet clover, legumes and silage. Feeding stuffs contributing even a smaller degree of off-flavor include: corn silage, green corn, green rye, potatoes, alfalfa hay, and grass. Feed flavors are more pronounced in the cream or fat. Feeding immediately after milking is the key to preventing these flavors. Cows should not be fed strong-flavor producing feeds within 5 hours before milking. As with weed flavors, vaccum treatment of milk prior to pasteurization has been found satisfactory in removing strong feed flavors.

There are a group of flavors which are incidentally related to feed, and may help predispose off-flavor development, although they are triggered by other factors than feed. Mild oxidation, induced by copper, affects phospholipids and vitamin C, for example. Often the individualty of the cow is a factor in this tallowy or cardboard flavor, but succulent pasture often helps overcome this defect. A simple change in feeds sometimes helps too.

Other factors are involved like exposure to light, but they are not related to feed. Rancidity can not only be oxidative, as with the development of cardboard and tallowy flavors, but

even can give stronger flavors when enzymes or water break down the fat of milk. This is a serious defect in butter, and should be guarded against in all ways possible. Yet rancidity does not appear to be related directly to feed.

A word can be added about the use of condimental stock foods or tonics: authorities generally feel that these are unnecessary in efficient production of quality dairy products. Also, little is known about the effects on flavor or quality of new techniques of milk production involving thyroid active materials, live rumen organisms, etc.

The nutrient requirements of dairy cattle are considered more for normal growth, reproduction, and milk production.[1] Yet these feeding standards will not be followed blindly by the wise feeder, for they are not absolute rules but only approximate guides. They do list all of the important characteristics of a ration, such as protein quality, other vitamins and minerals needed, palatability, etc. But little is said about greater efficiency in milk production.

Quality feeds are important in the production of quality dairy products, and only with quality dairy products can we expect acceptance by the consumer—who might rather forget his nutrient needs in favor of something he just likes.

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1. National Academy of Sciences, National Research Council, "Nutrient Requirements of Domestic Animals," Number III. "Nutrient Requirements of Dairy Cattle." Revised 1956.

Higher Quality Meat Products

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May, 1959

BEFORE I say very much about the subject of quality meat products, I must give you a little background information about current meat buying habits of consumers and their reactions to meat in general.

How Is Meat Quality Defined?

There are many differences between a textbook definition of quality in meat and that which consumers may assume about this subject. The consumer generally thinks the best indexes to excellence or goodness of meat are color, texture, firmness and the amount of lean. These attributes are believed to be good indicators of the flavor, juiciness and tenderness of cooked meat. Not many people are interested in excessively fat beef, pork or lamb. But in actual practice, most beef, lamb, veal and pork carcasses before they are cut up and prepared for retail sale, are graded in accordance with specific standards for finish (the amount and distribution of fat), conformation, the appearance of the lean and fat tissue, the character of the bone, and age and sex of the animals.

Meat Must Sell Itself

This method of defining meat quality is not always applicable to the large numbers of different kinds of fresh meat cuts, processed meats, and table-ready meats we find in our supermarkets nor can it be used to describe the nutritive value of meats. Modern merchandizing techniques which

emphasize careful and extensive trimming of excess fat, removal of bone, shaping of cuts so that they may be attractively displayed and conveniently prepared by the housewife for the family meal, greatly alters the appearance of many retail cuts of meat. The retail sale of meat has been tremendously simplified in the modern impersonal and highly efficient supermarket which has displaced the corner meatshop, the meat salesman and the butcher who once helped housewives make their meat purchases. Meat consumers do not see carcasses on disply. There are few meat salesmen behind counters; the shopper makes all the decisions. How are these decisions made? On some valid basis for quality appraisal, on impulse, the result of habit, on information gained from meat advertisements, from radio talks, from schools and colleges, from experience? These are all extremely pertinent questions but we do not have time to discuss them, only their implications.

The first sale of a product is based largely on appearance. Repeat meat sales will occur if the consumer gets what he thinks he is buying. It is in this connection that aroma, flavor, tenderness and juiciness, the attributes we associate with palatability in meats, become so important. These are the more obvious factors which influence the consumers' attitudes towards meats. Meat must look good, hence we must produce animals whose carcasses can be fashioned into attractively colored, firm, meaty cuts and meat products. Time does not permit further elaboration of these considerations for we are obliged to say something about the relationship between good nutrition and carcass quality.

Influence of Nutrition on Meat Quality

It should be completely reasonable to assume that the most nutritious meat products will come from healthy, well nourished animals allowed to grow at their maximum rate from birth to market weight. Poor nutrition will result in a poorly developed animal whose carcass composition may be abnormal, too thin or too fat, lacking in specific vitamin and mineral stores. We know that we can increase the thiamine content of pork by feeding extra thiamine. However, we are far less certain about the effect of poor nutrition on the amino acid content of individual muscle proteins or the composition

of muscle as such. There is no magic in nutrition. Good animal diets must contain adequate amounts of protein, energy, vitamins and minerals. The commercial development of low-cost vitamin and mineral supplements, and the abundant supplies of carefully manufactured protein supplements, particularly soybean meal, coupled with our present knowledge of the nutrient requirements of animals has given corn a much improved position as a livestock feed, particularly for pigs and poultry.

The once widely held belief that corn was suitable only to produce lard is no longer true. Properly supplemented with soybean meal or other high quality protein sources, minerals and certain vitamins, corn can be used to produce hog carcasses which will satisfy consumer demand for meaty pork. It is for this reason that pasture feeding, high fiber rations, limited feeding and other procedures for producing lean pork are not receiving much emphasis now.

A number of studies have been made on the effect of high levels of protein on the conformation and carcass quality of the pig. Canadian, British, and American workers have reported data which taken as a whole indicate that pigs receiving high protein rations produce leaner carcasses than those on medium or low protein rations. However, it must be conceded that these differences were not consistently significant when protein feeding was increased beyond levels considered adequate for the pig.

The influence of unsaturated fats or oils on pork carcass quality is so well known that no detailed discussion about this is necessary but it is unfortunate that more data are not available concerning the effect of feeding of hard fats to pigs. Studies which have been reported would indicate that moderately low levels (less than 6—8 percent in the diet) do not adversely affect the firmness of body fat or the amounts of fat deposited in the carcass of the pig and that they can be advantageously used as energy sources if available cheap enough.

The use of a high calorie feed such as fat as an energy source presents no serious problem if we make certain that rations containing fats also provide adequate amounts of the essential amino acids and other nutrients.

The numerous comparative investigations which have been conducted on feeding of oats, wheat, barley, and corn to pigs, show that some differences in carcass quality can be observed. The fact that Canadian swine producers can produce high quality carcasses using barley as the primary feed in fattening, whereas corn belt farmers use corn, clearly shows that both are good swine feeds. The primary concern is that these rations be properly balanced with respect to the amino acids, vitamins, and minerals.

Most feeders are not concerned about the influence of the various kinds of feeds on the carcass quality of beef and lamb. The practice in the feedlot is invariably to feed a high energy ration of corn, hay, or legume supplemented with oilmeal protein, vitamins when needed, and minerals. Practices vary of course, since the availability of beet tops, silage, and cereal grains for example, in certain areas provide alternate feeds for cattle and lamb rations. It is generally conceded that if these animals are fattened in the feedlot using corn, soybean meal and hay or other forage, excellent carcasses can be produced. Corn is an ideal feed for it is relished by these animals, provides a cheap source of calories and we have an abundance of it. It can also be pointed out that soybean meal has an excellent distribution of amino acids.

Use of Feed Additives

A large variety of feed additives are now being used to produce beef and lamb. There are many claims that they improve carcass quality but my view is that while some show considerable promise it is premature to draw definite conclusions about them now. Increased rate of gain is of great economic importance but it does not follow that increases in rate of gain necessarily enhance carcass quality.

Summary

We ought to be less concerned about the varieties of feeds we use, more with what nutrients they can provide to the animal. This is the basis for modern meat animal production and the only certain way towards achieving the production of healthy well nourished animals. If well muscled pigs are fed faulty diets (too many calories, not enough protein, or

lacking in minerals or vitamins) we cannot expect to produce a good carcass. On the other hand good nutrition cannot be expected to result in a high quality carcass if the animal has the genetic tendency to produce an inferior carcass and to grow slowly. We need only to look at the achievements of the broiler industry to accept the relevancy of this fact.

Low-cost Feed Formulation

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THE problem of mixed feeds for animals calls for close cooperation between the nutritionist, the economist, and the statistician. In technical language their problem is to find the "optimum feasible mixture." To be feasible, the mixture must satisfy the nutritionist and the feed industry. To be optimum, it must satisfy the economist—that is, it must be as inexpensive as possible.

Less than 10 years ago, Dantzig[1] published the first technical article describing "linear programming," which is a procedure for finding optimum feasible mixtures. In my opinion, linear programming is one of the most important statistical methods developed in the current century. It can be applied to a wide variety of economic problems, including the problem of mixed feeds.

Specifications

When the programmer talks about the feasible mixture, he means one that is acceptable, satisfactory, and approved. In other words, a feasible mixture is one that meets all the specifications that have been agreed upon by nutritionists, by feed manufacturers, and by farmers. The economist does not determine the specifications. He takes whatever specifications are generally accepted by the feed industry.

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[1]Dantzig, G. B., "Maximization of a Linear Function of Variables Subject to Linear Inequalities", in T. C. Koopmans (ed.), *Activity* Analysis of Production and Allocation, pp. 339—347, John Wiley & Sons, Inc., New York, 1951.

These specifications may include many things. In all cases they doubtless will include minimum allowances of proteins, calcium, vitamins, and other nutritional elements. In addition, they will commonly include minimum or maximum allowances for specific ingredients. They will usually include specifications for weight and bulk.

We have found so far that the most difficult and time-consuming job is that of setting down all the specifications in concrete, mathematical terms. If the statistician is to help find an optimum feasible mixture of feeds he must start with a system of equations and inequations representing the specifications for a feasible mixture. The whole process of linear programming will break down completely unless the equations and inequations are accurate and complete.

Luckily, the economist and the animal nutritionist in the United States have been working together in the past few years to get complete and accurate specifications for many kinds of mixed feeds. But there is still much to do along this line.

Content of Ingredients

In addition to having an accurate and complete statement of specifications, the statistician has to know the content of each of the possible ingredients that he might consider putting into the mixture. Here he needs to work primarily with the chemist. He needs the best research findings concerning the amounts of minerals and vitamins in each of the grains, mill feeds, and other potential ingredients in the mixture.

This, too, is a difficult problem. Consider any single ingredient. Take corn, for example. The chemical content of corn is not fixed and immutable like the laws of the Medes and Persians. It varies from year to year, from region to region, from variety to variety, and from grade to grade. Usually, we must work with some sort of average data, or perhaps with minimums. For example, we might be reasonably sure that a lot of soybean oilmeal would contain at least 40 percent protein. It might contain considerably more. The economist and statistician can, if necessary, work with such data on minimum content and grades. But if they can get more accurate data their analysis will also be more accurate.

Perhaps a word should be said here about tolerances; that

is, allowances that are commonly made to make sure that a mixture will at least meet minimum requirements. Suppose, for example, that you want a mixed feed containing 20 percent protein. Suppose, further, that you do not know accurately the amount of protein in the ingredients. Perhaps the estimates of protein content in the ingredients are subject to errors as high as 15 percent. You can still be sure of meeting the minimum protein requirement of 20 percent in either of two ways. First, you can substract 15 percent from the estimated protein content of each ingredient. Or, second, you can add 15 percent to the stated requirement, making it 23 percent instead of 20 percent. I understand that such tolerances are commonly used in the feed industry. Perhaps some tolerances may be necessary evils. But I think our objective should be to squeeze this tolerance down as far as we possibly can. This calls for further quantitative research in chemistry and related fields.

Doubtless you can be sure of getting a protein content of at least 20 percent by computing one that is supposed to contain 23 percent. This is like the builder of a bridge that is planned to carry a load of 20 tons. The engineer can play it safe by building a bridge that is computed to carry 30 tons. I understand this is often done in bridge building. As an economist, this sort of tolerance seems to me unscientific and expensive.

Prices

Finally, to find the optimum feasible mixture, we always need accurate data on prices. Fortunately, this is not hard to get. In the United States, at least, we have frequent and accurate information on prices in all the principal wholesale markets.

Electronic Computation

This is hardly the place to present a full, mathematical discussion of linear programming. I hope many of you will want to study the technical and theoretical aspects of this subject. For this purpose I highly recommend a recent book by Dorfman, Samuelson, and Solow.[2] I also highly recommend

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[2]Dorfman, Robert, Samuelson, Paul A., and Solow, Robert M., "Linear Programming and Economic Analysis." McGraw-Hill Book Co., Inc. N.Y. 1958.

several articles and reports by Professor Hutton[3] and his associates at the Pennsylvania State University. In addition, some of you may want to read a number of articles that have appeared in the Journal of Farm Economics[4] in recent years dealing with the economics of feed mixtures.

The methods of linear programming that are being most commonly used today are essentially those proposed by Dantzig in 1951. They involve two principal steps: First, a feasible solution is found satisfying all the equations and inequations, second, all possible substitutions are considered, and any substitution is made if it would reduce the cost without upsetting any of the equations or inequations.

Actually, this method is not too hard to understand, but it is a dreary chore to make by hand all of the computations that are needed. This is no problem at all when you have an electronic computer to do the work. If you have accurate data and if you plug the right program into the computer, all you have to do is press a button, sit back, and in a very few minutes you will get the answer.

Probably most feed manufacturers will have to take this on faith. Some of them may know very little mathematics. They even may dislike the subject. But they may find it pays to hire a statistician who knows what to put into the machine.

In any case, I understand that several of the largest feed mills in the United States are using electronic computers to find least-cost feasible mixtures of feed and to keep them up-to-date. Some of these mills have even bought the largest and most expensive electronic equipment for this sole purpose. I understand that some other feed concerns, including some of the large cooperative associations, have been doing some research to check their present feed mixtures and to find out whether substantial savings might be possible through the regular use of linear programming methods.

Main Principle of Linear Programming

Still, I think that better programming will be done when

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[3]Especially see Hutton, Robert F., King, Gordon A., and Boucher, Robert V., "A Least-Cost Broiler Feed Formula." USDA. Production Research Report No. 20. May 1958.

[4]One of the pioneering papers was Fisher, Walter D. and Schruben, Leonard W., "Linear Programming Applied to Feed-Mixing under Different Price Conditions." Journal of Farm Economics. Nov. 1953.

the top executives understand the basic principle involved.

For practical purposes I think the feed manufacturer can ignore at least half of the work that is usually done on the electronic computer and explained at length in the texts. That is, I think he can forget about the problem of finding a feasible mixture. If he is already in the feed business, he has been selling a mixture that was feasible. If it was feasible last week, last month, or last year, it is still feasible unless and until the specifications are changed. Even if he has never been in the feed business before, he can find a feasible solution in any textbook on feeds and feeding, or he can write to the agricultural college to find a mixture that will meet specifications.

The problem confronting the feed manufacturer is that of considering all possible changes which could reduce the cost of the mixture, still keeping it feasible. The key to linear programming is the principle of finding cost-reducing substitutes.

To understand this principle requires some familiarity with mathematics. Yet, anyone who really learned how to solve simultaneous equations when he went to high school should know enough mathematics for this purpose. Ordinarily, a mixture of four ingredients will just supply four requirements; a mixture of five ingredients will just supply five requirements; etc. Suppose we start with a mixture of five ingredients just supplying five requirements—and supplying more than the required amounts of some of the nutrients. We want to find out whether we could save money by substituting a new ingredient—for example, say, oats. Suppose 1 pound of oats were added to the mixture. At the same time, suppose we made adjustments (up or down) in the quantities of each of the five ingredients in the present mixture. These adjustments in ingredients would be such that the five requirements that had been just met by the former mixture would still be just met. Such adjustments can be computed by solving five simultaneous equations to find five unknown quantities. These quantities are the adjustments in each of the five ingredients in the present mixture. The computations can be made in any way that is most convenient. It is not necessary to be familiar with matrix computations, for example.

In the example mentioned above, the substitution of oats

would be feasible until it either: (1) completely replaced one of the ingredients in the former mixture, or (2) failed to satisfy one of the other specifications. Whether it would save money depends on the price of oats and the prices of the five other ingredients. Anyone can compute very quickly the saving or loss from such a substitution. Usually he will want to list all substitutions that would save money. Then he would want to make the substitution that would save the most money. After making one substitution, he would, of course, look for others that could make further savings. Sooner or later this process would end because there would be no more savings to make. This is what the mathematicians call an iterative solution; that is, it is a step-by-step solution, each step bringing us closer to the goal of an optimum or least-cost mixture.

Simple Methods

Most of the literature on linear programming discusses methods that are applicable mainly to electronic computation. In actual practice, many practical mixing problems can be solved with very elementary methods. Graphic methods[5] are especially easy and quick. Their use, however, is limited mainly to problems involving only a few specifications. With graphic methods alone it would be very difficult to find a mixture that would satisfy the broiler experts who insist on meeting more than 20 different specifications.

Even fairly complicated problems can be solved, using nothing more difficult than good, old-fashioned arithmetic. Unfortunately, arithmetic is sadly neglected today—at least in the United States. A century or more ago the arithmetic books in the English language included a subject called "alligation."[6] This was a set of rules for mixing ingredients to meet specifications. I believe that school children in other countries learned a similar process. The French and Spanish books probably used a word very similar to alligation. The Germans, Scandinavians, and other nationalities used different words.

[5]Waugh, Frederick V., "The Minimum-Cost Dairy Feed." Journal of Farm Economics. August, 1951.
Waugh, F. and Burrows, G., "A Short-cut to Linear Programming." Econometrica, January, 1955.

[6]Waugh, Frederick V., "Alligation, Forerunner of Linear Programming." Journal of Farm Economics. February, 1958.

But I think in all of these countries the school children learned simple, arithmetic rules for mixing ingredients. Ordinarily, the rules in the school books showed only how to mix two or more ingredients to meet a single specification. However, these rules can be easily extended to find mixtures that will meet a number of specifications. Actually, one of our statistical clerks learned the process of alligation in not more than half an hour, and worked out the optimum feasible mixture of broiler feeds by the process of alligation. The same problem was analyzed on the electronic computer at Pennsylvania State University. The results, of course, were the same.

The advantage of the electronic computer is, of course, that after you get the thing properly programmed it will do everything automatically and quickly. Yet, I think it is a good thing to understand what the machine is doing. Therefore, I highly recommend some experimenting with simple arithmetic and graphic analysis.

Dreams of the Future

The progress of linear programming has been extraordinarily rapid. It is being applied to a wide variety of practical problems, including the mixing of animal feeds. In fact, some of the best work done to date has been in the field of animal feeds. The trade journals, such as *Feedstuffs*[7] in the United States, have carried interesting and informative articles on the subject.

The statisticians have the whole operation programmed for an electronic computer. If the feed manufacturer knows the correct specifications for a mixed feed, and if he knows the contents and prices of each ingredient, he can put all this information on a tape, put the tape in the machine, push a button and get the answer. The whole thing is completely mechanical. It requires no imagination.

How far this may go in the future is anyone's guess. It could go much further than it has yet. It is easy to dream of a robot factory that is actually run by an electronic computer. The computer would not only discover the least-cost optimum

[7]Hutton, Robert F., "Use of Linear Programming in Feed Manufacturing." A series of seven articles in successive issues of *Feedstuffs*, beginning September 27 and ending November 8, 1958.

feasible mix, it would actually open and close shutes in the mill and do all the mixing. Moreover, the machines will write checks. I see no reason why some imaginative inventor might not rig up the machine so it would order the feed, pay for it, mix it, sell it, and collect the money. The manager might go to Florida and let the machine run the business. If we really let our imagination go, we wouldn't have to stop with an animal feed industry that runs itself. Perhaps the electronic computer might not only run the feed mill, but actually feed the mixture to the chickens. Perhaps the farmer could join the feed manufacturer on the sands of Miami Beach. They would need only to train the machine to pay their hotel bills regularly.

Of course, these remarks are fanciful pipedreams. Automation is making some progress. Doubtless it will make more. But for some time, at least, the farmer and the feed manufacturer will have real jobs to do. Even the big manufacturers who can afford an electronic computer will need a competent man to tell the machine what to do. And I think many small feed manufacturers and cooperative associations will find that they can do linear programming with very inexpensive equipment, or none at all. The poor man's programming may be done with charts and simple arithmetic, with perhaps some help from an old desk computer. The college or the trade association may use an electronic computer to help the feed manufacturer make the more difficult computations. But anyone can do the easy figuring needed to adjust a feasible mixture to take advantage of week-to-week changes in prices.

Safeguarding Feed Users

By L. Y. BALLENTINE
Commissioner of Agriculture for North Carolina

LEGAL safeguards for users of feeds and other products do not represent a new idea. At various stages of history the governments of various countries have attempted to prevent such practices as putting chalk in flour, water in milk, or sawdust in feeds.

In general, however, feed control and similar programs have developed with industrialization and with increases and concentrations of populations. In ancient agrarian societies, when almost every family produced and hand processed its own feedstuffs, the user was safeguarding his own interests.

As populations increased and became concentrated in cities and towns, the need for food and livestock production increased proportionately. Urban populations could no longer depend upon the farmer's chance surplus for their food supplies. Farmers had to plan their production to feed other families beside their own. The long, slow process of crushing and mixing feed by hand did not permit the farmer to produce the quantity of livestock needed to fill the demand; and so the feed manufacturer came into existence. Then the farmer, himself, became a kind of manufacturer, buying the products of one industry for conversion into another product which is, in turn, converted or processed by still other industries. The quality and volume of his production depends in large measure upon the quality of the materials that go into it. His profit or loss may depend upon whether or not he gets fair value for the materials of production he has to buy.

But here in America, safeguarding the interests of the feed

user involves much more than the farmer's profit or loss. Industrialization of this country has been rapid. Since 1910 the farm population has decreased from 35 percent of the total to about 12 percent, and this ratio is continuing to decline. Fewer and fewer farmers must produce food for more and more people, and to do this they must operate at top efficiency. Therefore, safeguarding the interests of the feed user is one way of safeguarding the interests of a nation.

The commercial feed industry in America had its beginning during the latter part of the nineteenth century and the early years of the twentieth century. Feed laws quickly followed. In 1894 New York enacted the first State law to regulate processors of byproduct ingredients and manufacturers of mixed feeds. Today 47 States enforce feed laws and regulations.

The feed control program has had the support and cooperation of the feed industry at every stage of its development. Members of the industry have had the vision to see the controls as an assurance of uniformly desirable qualities in feeds to earn and keep the confidence of feed users.

And the feed industry has benefited in other ways. The control program has pointed up the close interrelationship of the industry's welfare with that of the farmer. It caused manufacturers to establish their own control laboratories, and from these have come the industry's research laboratories. This in turn has led to the industry's cooperation with feed and nutrition research at government laboratories and in land-grant colleges.

Out of this kind of cooperation have come the discoveries which have played such a large part in sharply expanding the production and consumption of livestock—discoveries such as cheaper or more efficient sources of proteins and carbohydrates; nutrition in fibers previously thought to be without food value; medicated feeds that have removed the ever-present danger of certain diseases sweeping through herds and flocks; hormones to increase the rate of fattening livestock and poultry; and many other materials and methods that have sharply increased the rate of feed conversion—the pounds of meat per found of feed. For instance, in 1940 it took $4\frac{1}{2}$ pounds of feed to produce a pound of meat in the production

of broilers. Today it takes just half that amount of feed to produce a pound of broiler meat, and the meat is of better quality. The feed industry has made a major contribution to all these achievements.

Early Feed Laws

The first feed laws were intended primarily as economic safeguards. They were designed to assure that the farmer got all the basic food elements he paid for. As science has developed more information about animal nutrition, however, it has become evident that the kind or source of food elements are often as important as the amount, and that animals vary as to the kind of proteins or other food elements they can best utilize. It became necessary to set standards for special-purpose feeds and to provide safeguards against abuse or misuse of feed formulas.

From the very beginning it was recognized that uniformity in State laws is an important safeguard for feed users. The feed user would ultimately pay the increased cost for a diversity of provisions making it necessary for manufacturers to print different labels, or compound different formulas, for each State in which they do business. As early as 1910 a National Association of Feed Control Officials was formed, and from that day to this, one of its major purposes has been to achieve as much uniformity as possible in requirements. As a result, feeds move freely across State lines, and differences in requirements usually involve only administrative procedures or minor variations needed to fit particular situations in individual States. Thus, the North Carolina feed law and regulations, around which this discussion centers, are not basically different from those of other states.

North Carolina Law

The feed law itself is, for the most part, only the framework for the program. Regulatory details for such a technical industry would be undue burden on the lawmaking body. Therefore, the law authorizes the State Board of Agriculture to make rules and regulations within the framework of the law; and such rules and regulations have the full weight of law.

The Board of Agriculture consists of 10 members, all

practical farmers. They are appointed by the Governor of the State, who is himself elected by the people. Each member is appointed for a term of 6 years, and it is not unusual for members to be reappointed by several governors for several consecutive terms. Also the members' terms of office overlap, so that not all the appointments can expire at one time.

Named by law as chairman of the Board is the Commissioner of Agriculture who is also elected by the people. Administration of the feed law and regulations is one of his duties. He is elected for a 4-year term, but in 60 years there has not been a North Carolina Commissioner of Agriculture who was not reelected at least once, most of them several times.

Thus, it will be seen that there has been continuity in both the regulatory and administrative phases of the State's control programs. Those charged with these responsibilities have had time to gain broad understanding of the problems involved, and to experience the year-to-year development of new techniques and practices requiring regulations.

Before the Board of Agriculture takes any regulatory action, a public hearing is called. Feed users and manufacturers are notified by legal advertising, newspaper articles, and through the farm and trade associations. Animal nutrition scientists from the land-grant college are asked to attend the hearing; and also officials of the State Department of Health if proposed regulations have any bearing on human health.

All interested persons are given an opportunity to express their views. Then the Board members consider the various opinions expressed, consult the scientists for such technical information as they need, and take whatever action seems to be in the best interest of the feed user; always bearing in mind that unnecessary and cost-increasing restrictions on feed manufacturer are not in the best interest of the user.

The Board also tries to keep the State regulations as nearly uniform with those of other States as conditions permit; although it must be realized that as new situations arise some one State must inevitably be the first to take action. Usually, however, any major change in regulation is first discussed between control officials of the various States, and

recommendations are made to guide the regulatory body toward uniform measures.

In North Carolina, as in many other States, the feed control program has three phases—the law, the regulations, and the administrative procedures. But the three are so closely tied together that they cannot be separated in discussing the various measures for safeguarding feed users. However, I will begin by a mere listing of the major provisions of the feed law itself. Briefly, these cover: (1) labeling; (2) registration and guarantees; (3) inspection and sampling; (4) laboratory analysis; and (5) penalties for violations and other enforcement procedures.

The law applies only to the so-called commercial feeds—crushed, ground, and mixed feeds, the quality of which can be determined only by laboratory analysis. Therefore, as I use the word "feeds" in this discussion, it will refer only to such commercial mixed feeds.

The labeling provisions of the law require that any container or package of feed shall have on it a conspicuously printed statement giving the brand or trademark of the feed, the name and address of its manufacturer or importer, its weight, a complete list of its ingredients, a guarantee that the contents are pure and unadulterated, and the percentages of crude fiber, crude fat, and crude protein. If the feed is sold in bulk and is not packaged, this information must be furnished the puchaser on a printed card.

To these provisions of the law, the Board of Agriculture has added regulations requiring statements as to the kind and source of screenings used in feed. Regulations also require special cautionary labels for feeds containing urea and ammonium salts (permitted in feeds for ruminants only), medicated feeds, and feeds containing hormones. These cautionary labels must include such information as the species and age of animals for which the feed is intended, the time before slaughter when a feed should be withdrawn, and similar instructions based on scientific knowledge and recommendations from the federal and state research agencies.

Other miscellaneous labeling regulations prohibit the use of printed matter or pictures which would in any way mislead the purchaser as to the quality or purpose of a feed.

But before any feed may be sold in North Carolina, it must be registered with the Commissioner of Agriculture. Some one person or firm—manufacturer, importer, jobber, agent, dealer—must register and assume responsibility for the quality of each distinct brand of feed sold. Application for registration must be accompanied by a statement containing all the information and guarantees required to be printed on the label. Registrations must be renewed annually.

The Commissioner has authority to refuse to register a feed if its brand name or labeling are misleading, or if it fails in any way to comply with the law or regulations. And, if a feed is registered and it is later found to be in violation of the legal requirements, the Commissioner has authority to cancel the registration.

Once a brand of feed has been registered, its guaranty or label may not be modified during the registration period if such change lowers the quality of the feed.

In addition to meeting the guarantees and claims made by the registrant, certain worthless substances, such as chaff or hulls, and ingredients injurious to animals are prohibited in feeds. Certain other ingredients are limited as to amount. And the regulations set minimum standards for all special-purpose feeds, chemical standards for seed meals, and fiber standards for mill byproducts sold as feed.

Feed inspectors travel assigned territories to cover the entire State. These inspectors have two major responsibilities. First, they must check to make sure that any feed they find offered for sale is properly registered and labeled. Then they must take an official sample of the feed to send to the laboratory for analysis. Samples are taken by carefully prescribed methods, so that each sample will be truly representative of the entire "lot" of each brand sampled.

Analytical methods are also carefully prescribed. The law requires that they shall "conform to sound laboratory practices as evidenced by methods prescribed by the Association of Official Agricultural Chemists of the United States." This is another provision in the interest of uniformity, as well as accuracy.

If analysis shows that a feed fails to meet the guarantees made for it, the law requires that a financial penalty be

collected from the guarantor and paid to the purchaser to reimburse him for the deficiency. The amount of such penalty is computed on the basis of rates specified in the law and these rates vary with the extent and nature of the deficiency.

Other enforcement measures are also provided in the law. Feeds falling below minimum standards or substantially below guarantees, and containing substances injurious to animals, may be condemned and seized. In cases of willful or repeated violations of the law, the persons responsible may be prosecuted in the courts.

Another effective control measure is a provision in the law authorizing publication of the results of analyses of official feed samples. Once each month a farm paper published by the Department of Agriculture carries a tabulation of feeds that failed to meet the guarantees. An annual report is printed showing the results of analyses of all official samples tested during the year.

Cooperative Aspects

These are the major provisions of the law and regulations. But there is an important aspect to the program for safeguarding feed users that is not written into these codes. I refer to the attitude of feed control and regulatory agencies—an attitude which I believe generally prevails in all the States. Control officials do not have as their major objective the "catching" of offenders, but the prevention of offenses. They consider education to be as important as enforcement in administering control measures. They and their inspectors, in working with manufacturers and dealers, help to bring about better compliance with it.

And control officials know that they must cooperate closely with agricultural research agencies, the feed industry, and the feed user if safeguards are to be most effective. The regulatory agencies must be guided by research recommendations. They must give due consideration to technical problems of the industry. They must be alert to the needs of the user. Only this kind of broad approach could make possible the almost miraculous progress in scientific feeding which has taken place in America during the last half-century.

Such cooperative methods are used in arriving at both legal and regulatory provisions. Every precaution is taken to safeguard the interests not only of the feed user, but also of the consumer who eats the meat of animals given such feed. In this country we have full confidence in our feed products containing additives, as all must have approval based on extensive testing and evaluation.

A Food Additive Amendment to the Federal Food, Drug and Cosmetic Act was enacted last year, which gives still better assurance of quality and desirability. The term 'food' in the Act is so defined as to include animal feeds as well as human food. In the past, the Food and Drug Administration had to prove an additive was harmful before its use could be prohibited. Under the new law, manufacturers are required to prove that the new additive is safe before the Food and Drug Administration approves its use.

Research is constantly bringing to light new materials, new practices, new discoveries. Regulations must not hamper progress, but they must be based on sound, impartial scientific research. In the first flush of enthusiasm for new discoveries, farmers and the feed industry sometimes ask measures that have not been adequately tested in all their aspects. But the regulatory bodies and control officials are guided by the cautious hand of science, because their first obligation is to safeguard the feed user.

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Better Feed Products Through Pharmacology

By BERNARD L. OSER
Food and Drug Research Laboratories, Inc.

IF it had been possible to orbit one of our farmers into space some 50 years ago and bring him back today, he would most likely think he had landed on the wrong planet. So numerous and revolutionary have been the changes in agricultural practice since the turn of the century that he would probably not recognize the old place. He would find that machines have replaced men, horses, and mules. Where 1 farm worker provided food for 7 persons in 1900, he would find that he now produces for 20. He would learn that the production per manhour of labor had increased over 100 percent in the case of poultry, 90 percent for milk cows, only 25 percent for meat animals, but 350 percent for feed grains. Our returning farmer would discover that in the past 30 years egg production per hen had increased from 120 to nearly 200, that milk output per cow had risen from less than 5,000 to more than 6,000 pounds. Upon scanning today's farm journals he would be at a loss to understand the vast new terminology introduced since scientific nutrition came of age; he would find advertising columns devoted to chemicals and drugs and not merely to feeds and grains as in the old days.

Notwithstanding the advances made possible by the application of science and technology to agricultural production, our returning space traveller would find a world concerned with the realities of a problem prophesied by an Englishman named Malthus over a century ago. Examining further he would find that the world population had risen 70

percent since his flight into space, a rate of increase almost double that of the previous half century. He would find geneticists, bacteriologists, chemists, pharmacologists, physiologists, nutritionists, and scientists of many other stripes toiling away in laboratories and in the field searching and researching for more and better nutrition for animals and man.

Meeting World Food Needs

It is necessary that every possible means be invoked to meet the food requirements of our explosively expanding population. Conservation of arable land against the destructive forces of wind and water, increased production per farm acre, optimal efficiency in the conversion of plant foods to animal foods, protection of animals and crops against the ravages of disease and pests, facilities capable of storing the output of peak production periods or areas without losses due to intrinsic as well as extrinsic factors—these are but a few of the means whereby modern science is meeting the Malthusian challenge.

Scientific nutrition, as we understand it today, can be said to date from the development of the vitamin concept in 1912. Kaleidoscopic changes followed upon the discovery of each new vitamin. Identification, isolation, and eventual commercial production of the vitamins made it possible during the intervening years, to study the overall nutritional requirements of farm and domestic animals as well as of man himself. Each new discovery was followed by deeper probing into the beliefs of the past, and each probing yielded new byproducts and new discoveries. As a consequence, animal production is now less influenced by seasonal factors than in former years, and the feeds of today permit more efficient conversion of feed to food for man.

Despite these accomplishments we cannot afford to be complacent when we consider that the estimated economic loss of animals from disease, disorders, parasites, and insect pests was over $ 2.4 billion in 1954, representing 6 percent of potential production or about one-seventh the total value of farm marketings and home production (1).

1954 deaths (all causes except slaughter)

	Thousands
Cattle	1,500
Calves	2,500
Sheep and lambs	4,000
Swine	10,550
Chickens	235,000
Turkeys	7,200
Horses and mules	250

This is exclusive of preweaning deaths which, in the case of pigs, was said to number 30 millions.

Role of Nutrition Research in Disease Control

Of all the factors that have contributed to the phenomenal rise in output of animals and animal food products in the present century, by far the most significant has been the science of nutrition. From this area has come the knowledge of what constitutes better foods, how to produce them, and how to study the requirements of animals in health and disease. Our understanding of rickets, encephalomalacia, and hemorrhagic disease in chicks, of scours in calves, of night-blindness in pigs, and of many other diseases is a direct outgrowth of the newer knowledge of nutrition. Concomitantly with these developments has been the study of the nutritional requirements for optimal growth, reproduction, egg and milk production, etc., without which the discovery of new growth stimulants such as the estrogens and antibiotics would have been impossible.

Interest in the use of agricultural byproducts and in byproducts of the sugar, distillation, and fermentation industries as feed ingredients has prevailed for many years. It was the trial of an antibiotic residue as a source of vitamin B^{12} that led to the recognition of the growth-promoting value of chlortetracycline. Pharmacologic studies had indicated that this antibiotic possessed negligible toxicity. On the contrary it, and subsequently other antibiotics, were found not only to promote growth in poultry, swine, calves and other livestock, but to reduce morbidity and mortality as well. The effective-

ness of antibiotic supplementation in practice is dependent on the quality of the feed and on environmental factors, particularly from the sanitary standpoint. Their action is probably mediated through an effect on intestinal flora but whether by suppression of certain microorganisms and stimulation of others or indirectly by an effect on internal secretions, is not fully understood.

Classes of feed additives

Nutrients	*Medicaments*
Vitamins	Bacteriostats
Minerals	Antibiotics
Amino acids	Coccidiostats
Urea, Ammonium salts	Parasiticides
Alcohol	Anthelmintics
	Vitamins, etc.
Growth stimulants	*Adjuncts*
Hormones	Antioxidants
Estrogens	Antimycotics
Iodinated casein	Humectants
Antibiotics	Flavors
Arsonic Acids	Carriers
Tranquilizers	
Enzymes	

In this connection it is of interest to cite the case of arsanilic acid and related arsonic compounds which, in addition to being coccidiostats and parasiticides, have been shown to possess growth promoting potential at feed levels so low (45 to 90 g. per ton) as to present no question of hazard in the meat or other food products derived from the bird. The use of these compounds has increased in recent years on the basis of their demonstrated effects on growth, feathering and pigmentation in poultry and on the control of enteritis in hogs.

On the basis of recent studies (2) the question has been raised as to whether the continued use of antibiotics or other bacteriosasis might result in the development of resistant

strains of microorganisms and hence loss of effectiveness against subclinical infection. Further studies and careful observations under practical conditions will be needed to provide the answer to this question. The possibility that strains of intestinal microorganisms which are resistant to one antibiotic might ultimately predominate has led to successful trials with newer antibiotics (3). In any event it can be expected that pharmacological research and development in the field of antibiotics as dietary accessories will continue in the endeavor to establish their mode of action, to relate it to their chemical structure, and either by microbiological fermentation or by chemical synthesis, to produce compounds least likely to favor the development of resistant pathogens. Recent reports from England and the United States which attribute antibiotic activity to a portion of the penicillin molecule, produced by interruption of the fermentation process, are an encouraging augury to this end.

To protect the vitamin A and carotene content of feeds against oxidative destruction, antioxidants have been used. Many substances have been studied for their effectiveness not only in preserving these vitamins, but in the prevention of rancidity of fats in high-energy poultry feeds, and in the protection of natural or added tocopherols. The discovery that chick encephelomalacia resulted from dietary deficiency of vitamin E paved the way to greatly increased use of antioxidants in broiler rations. One consequence of this practice was the finding that diphenyl p-phenylenediamine (DPPD), a highly effective antioxidant, manifested an unusual form of toxicity when fed to pregnant rats, although tests and experience had shown it to have no adverse effect on growth, egg production, or hatchability in chickens. The use of this antioxidant was discontinued because slight residues could be detected analytically in the eggs and flesh of DPPD-fed poultry. Except for its effect in delaying parturition in rats, DPPD possesses a low order of toxicity, is apparently safe for poultry, and leaves an extremely minute residue in food. Under the newly enacted Food Additives Amendment of 1958, there is a possibility that a tolerance for DPPD in poultry products might be established provided its mode of action and species specificity are adequately established.

Investigations designed to develop more effective antioxidants have disclosed the fact that certain of them, like the sulfa drugs and other bacteriostatic compounds, may inhibit bacterial synthesis of vitamins in the intestinal tract. Poultry are quite susceptible to vitamin K deficiency as is indicated by the occurrence of hemorrhagic disease accompanied by hypoprothrombinemia. The synthetic analog of this vitamin, menadione bisulfite, is several times as effective as the natural vitamin and is used at levels of 1 g. per ton of feed or, when hemorrhagic symptoms are present, in the drinking water at a level of 10 mg. per gallon.

New Drugs and Their Safety Evaluation

Systematic evaluation of new compounds or classes of compounds for pharmacologic effects have likewise yielded preventive drugs for incorporation in improved animal feeds. Investigations of the therapeutic potentialities of aryl ureas revealed the fact that molecular complexes with carbanilides were antiparasitic (4). From this came nicarbazin, one of the most effective coccidiostats in use today. A similar story could be told about the pharmacological research that led to the development of the nitrofurans of which two have been in commercial use, nitrofurazone and furazolidone and another, furadroxyl (5), is in prospect.

It may be of interest at this point to emphasize the vast amount of research effort needed to establish not only the effectiveness but the safety of new feed ingredients under our Federal laws. After a substance has been produced from either a natural or synthetic source, and has been found to have nutritive, preventive, or therapeutic value as a drug or additive to animal feed, the process of obtaining legal sanction for its use begins. If it is a drug, an application must be made to the Food and Drug Administration to permit its sale in interstate commerce. Among the requirements which must be satisfied in a new drug application are detailed directions for use, full reports of investigations to establish the safety of the drug under the proposed conditions of use, and appropriate precautionary labeling. If the substance is a food additive, or if it is a drug which may become a food additive by virtue of its transfer into edible animal products, either as

such or as a metabolite, a petition regulating its use must be filed as provided in the new Food Additives Amendment. This requires the submission of information as to the composition, identity, analytical determination, and safety evaluation of the residual product. In the case of food additives, toxicological appraisal is generally based on 2-year feeding studies in rats and dogs involving extensive physiological and biochemical examinations. At the termination of the experimental period, autopsies and microscopic examinations of the organs are conducted. In the study of drugs or additives administered to poultry or livestock feed it may also be necessary to establish blood or tissue levels, rates of elimination from storage sites in the animal organism, compatibility with other constituents of the feed, including the more important drugs, and other data relevant to the appraisal of safety.

With this degree of regulatory control surrounding the introduction of new substances into feeds or foods there can be little question of the safety of modern animal feeding practice in the United States. It cannot be denied, however, that occasionally deaths have resulted from the incorporation into animal feeds of toxic ingredients, such as trichloroethylene-extracted soybean meal or fatty acids derived from an industrial tallow. These instances are rare but they stress the need for constant vigilance on the part of feed formulators.

That veterinary medicine is keeping pace with human medicine is indicated by the current interest in the use of ataraxic drugs. While this is still in the experimental stage, evidence is available to suggest that hydroxyzine, rauwolfia alkaloids, and phenothiazine derivatives, by virtue of their tranquilizing properties, may enhance growth rate and feed efficiency of beef cattle above and beyond that induced by hormones and antibiotics. Variable results have been observed in swine and lambs, however.

Trends in Mineral Nutrition

Since this paper is intended to emphasize contributions of pharmacological research to animal production, attention has been directed toward the uses in animal feed of nonnutritive substances which enhance growth, feed efficiency, and production, or which provide protection against diseases. It

should be remembered however that the pace of nutritional research has not diminished significantly since the heyday of the discovery of the major vitamins. Supplementation of some poor quality proteins with methionine and the partial replacement by urea of the protein in the ration of ruminants are now recognized practices. Interrelationships are being discovered among certain trace metal in the diet, such as copper, manganese, and molybdenum, which bid fair to open new avenues of research and to require re-examination of older concepts. The recent addition of selenium to the category of essential trace elements despite their toxicity in excessive dosage, suggests the possibility that much remains to be learned in the realm of mineral nutrition.

So far as developments in feed improvement are concerned the line between pharmacological and nutritional research is not sharply drawn. This is due in part to the specific role of various dietary constituents in the prevention or treatment of deficiency diseases and in part to the fact that medication for animals is often administered in their rations. The established roles of copper in the prevention of the nutritional anemia of weanling pigs, of manganese in perosis or slipped tendon of poultry, of iodine in goiter and of cobalt in anemia of ruminants, have led to the practice of incorporating these elements into commercial feeds.

Newer Developments in Animal Feeding

Considerable attention is currently being given to the possible role of enzymes as constituents of the ration of young pigs whose digestive secretions have not been fully established. There is some evidence that this may permit weaning as early as 2 weeks instead of the customary 5 weeks. However such findings are not consistently observed and enzymes and feed additives must still be considered in the experimental stage. Large scale feeding experiments are under way to determine the extent to which relatively low concentrations of ethyl alcohol may be employed in liquid feeds as a source of energy for cattle. Whether tranquilizers offer sufficiently great and consistent advantages for beef cattle or other livestock to justify their use in practice, is likewise under investigation. In this connection it is worth considering whether mere increase

in body weight without regard to the composition of the increment is a suitable basis for evaluating the effectiveness of a feed ingredient.

In the time allotted for the presentation of this paper, it has not been possible to delve deeply into any particular phase of the science and technology of animal feeding. However it should be clear that tremendous progress has been made, especially during the last half century, so that today we have the maximum output of all time with respect to both the productivity of the individual animal, and the actual numbers of poultry and livestock, with a concomitant reduction in manhours of labour required for their production. Little, if any, of this progress would have been possible without research in the cognate fields of animal nutrition, pharmacology and medicine. We can look forward to continuing efforts of scientists in these and other areas to raise still higher the standards of production and in this way help meet the needs of a rapidly expanding world population.

Literature Cited

(1) Nordquist, A.V. and Pals, C.H., U.S. Department of Agriculture, Yearbook of Agriculture, p. 11 (1956).
(2) Libby, D.A. and Scharble, P.J., Science, *121*, 733 (1955).
(3) McGinnis, J., Merrill, L.H., Fry, R.T., Jensen, L.S., Poultry Sc., *37*, 810 (1958).
(4) Ott, W., Kuna, S., Porter, C.C., and Cuckler, A.C., Poultry Sci. *35*, 1355 (1956).
(5) Creek, R.D., Dendy, M.Y., and Hinners, S.W., Poultry Sci. *38*, 145 (1959).

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